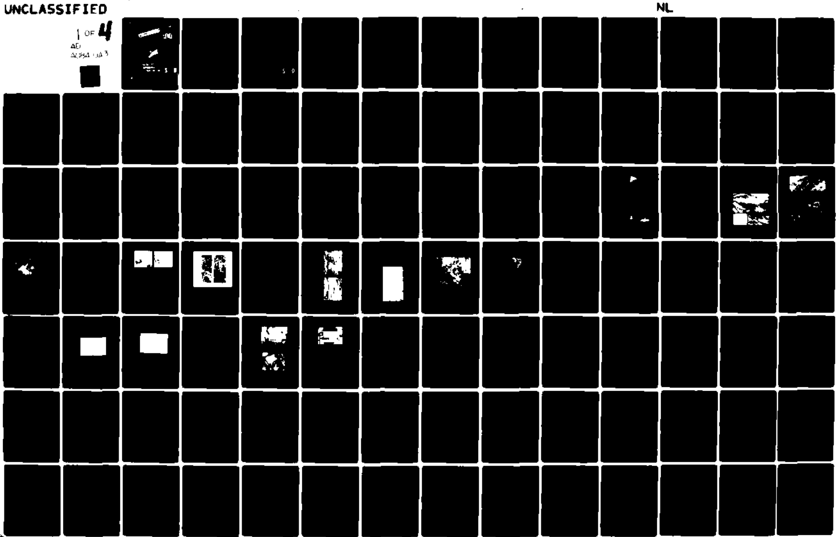
AD-A084 043 ARMY ENGINEER TOPOGRAPHIC LABS FORT BELVOIR VA F/G 17/8
U. S. ARMY CORPS OF ENGINEERS REMOTE SENSING SYMPOSIUM, 29 - 31--ETC(U)
OCT 79

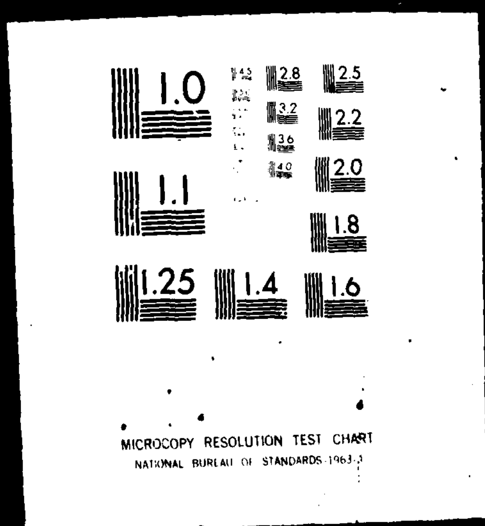
UNCLASSIFIED NL

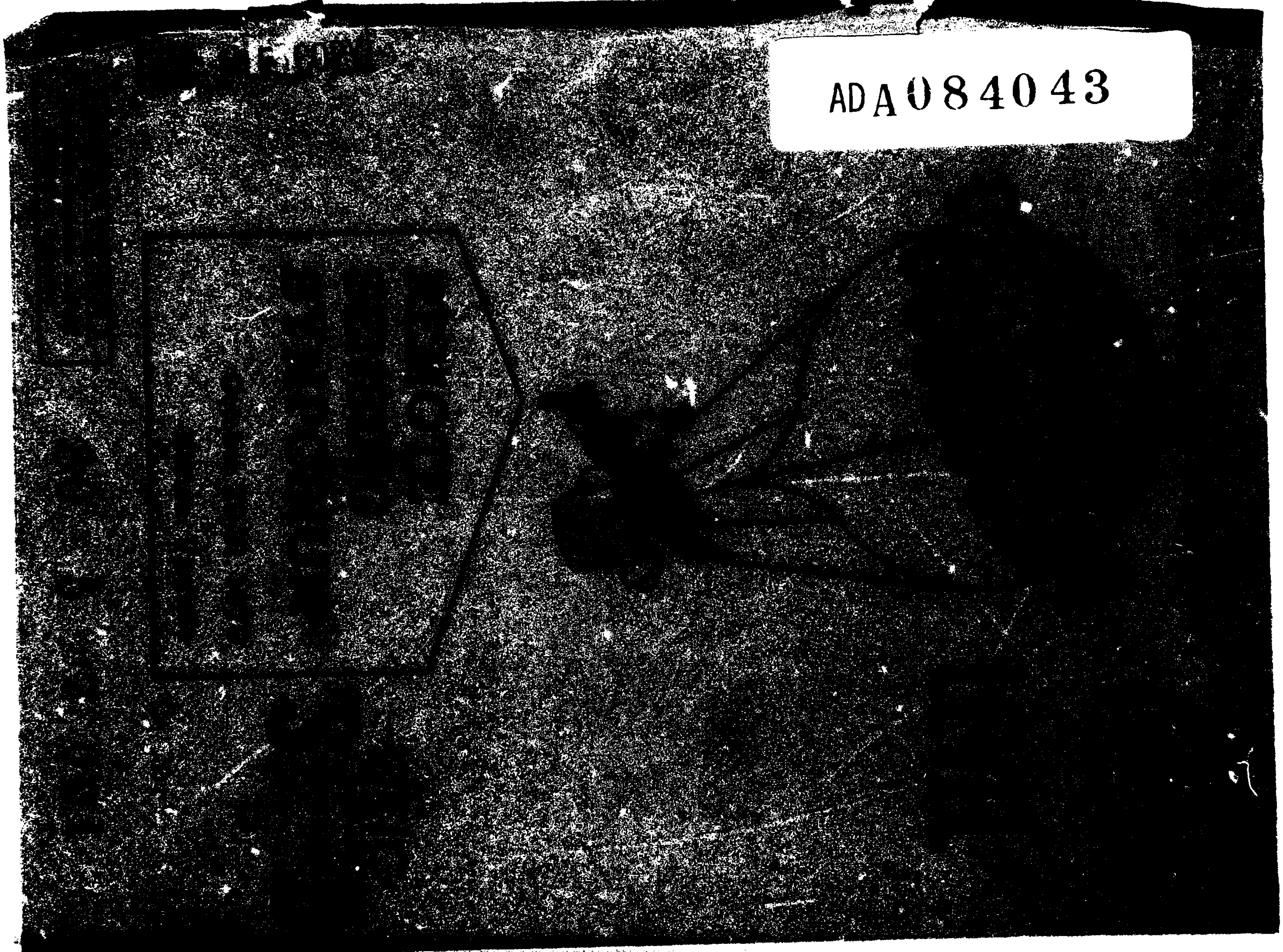
1 OF 4
AD
A084043



1 OF 4

AD
A084 043





UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A084043	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PROCEEDINGS FOR U.S. ARMY CORPS OF ENGINEERS REMOTE SENSING SYMPOSIUM		5. TYPE OF REPORT & PERIOD COVERED Proceedings 29-31 October 1979
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer Topographic Laboratories Fort Belvoir, Virginia		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer Topographic Laboratories Fort Belvoir, Virginia		12. REPORT DATE 29-31 October 1979
		13. NUMBER OF PAGES 410
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains presentations made at the U.S. Army Corps of Engineers Remote Sensing Symposium which was held to review the current state-of-the-art in remote sensing technology and detailed presentations on applications and the interrelationships existing among the Corps, other government organizations, academic institutions and industry in utilization of remote sensing technology.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

U. S. ARMY CORPS OF ENGINEERS

REMOTE SENSING SYMPOSIUM

29 - 31 October 1979

Held at

SHERATON INTERNATIONAL CONFERENCE CENTER
Reston, Virginia

ORGANIZED BY THE

U. S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES (ETL)

SPONSORED BY THE

CIVIL WORKS DIRECTORATE OFFICE, CHIEF OF ENGINEERS (OCE)

PROGRAM DIRECTORS

J. W. Jarman (OCE)

Frank R. Walden (ETL)

U.S. ARMY CORPS OF ENGINEERS

REMOTE SENSING SYMPOSIUM

29 - 31 October 1979

PREFACE

The Corps of Engineers has been conducting research and development (R&D) in remote sensing technology for a number of years and has reached the point where these efforts should be directed to supporting an operational base. Operational use will require the extracting of usable information from operating remote sensing systems, selecting and formatting of that information to fit the needs of the user and adapting the user's procedures to apply the information most effectively. This symposium was designed to provide representatives from the various Corps Divisions, Districts, and Laboratories with a brief overview of the current state-of-the-art in remote sensing technology and detailed presentations on applications and the interrelationships existing among the Corps, other government organizations, academic institutions and industry in utilization of remote sensing technology.

The Proceedings for the Corps of Engineers Remote Sensing Symposium documents the majority of the multidisciplinary technical and poster session papers presented at this symposium. It should be noted that since documentation of the presentations was made on a voluntary basis, the contents of the Proceedings may vary from a short summary to a complete paper. Attendees at the symposium who are interested in obtaining more information on presentations made at this symposium are encouraged to contact the participants directly.

We are grateful to the many authors who made this volume possible. We also express our appreciation to the secretaries for their assistance in typing and assembling this text.

Daniel L. Lycan

DANIEL L. LYCAN
Colonel, Corps of Engineers
Commander and Director
U.S. Army Engineer Topographic Laboratories

TABLE OF CONTENTS

*An asterisk indicates that an abstract or summary of this paper was not received in time for publication. Authors should be contacted directly for copies of their presentation.

PAGE

WELCOMING ADDRESS

Colonel Daniel L. Lycan
Commander and Director
U.S. Army Engineer Topographic Laboratories
Fort Belvoir, VA 22060

Colonel Lycan was appointed as Commander and Director in September 1978. He has held responsible command and staff assignments in both the United States and overseas. He served as Technical Assistant to the Deputy Chief of Engineers for NASA support, Office of the Chief of Engineers, Washington, D.C.; as the Department of the Army representative for the Department of Defense Manned Orbiting Laboratory Space Program, Office of the Secretary of the Air Force, Washington, D.C.; as Commander, 84th Engineer Battalion (Construction), Vietnam; as Commander, 45th Engineer Group (Construction), Vietnam; as Chief, Engineer Operations Advisory Branch, U.S. Military Assistance Command, Vietnam; as Deputy Commander and the Commander, U.S. Army Computer Systems Command Support Group, Presidio of San Francisco, California. Prior to his present assignment, he served as the District Engineer at Rock Island, Illinois. Colonel Lycan was commissioned in the Regular Army as a Distinguished Military Graduate from senior ROTC at the Massachusetts Institute of Technology, Cambridge, Massachusetts in 1952. He received a bachelor of science degree in civil engineering from MIT, a master of science degree and a Ph.D. in civil engineering from the University of Illinois. He is a graduate of the Army War College and the Army Command and General Staff College. He is a registered Professional Engineer in the State of Mississippi.

Good morning. I am Dan Lycan, Commander and Director of the Engineer Topographic Laboratories (ETL). It is my pleasure on behalf of the Chief of Engineers to welcome all of you to the Remote Sensing Symposium. I particularly welcome you who have had to travel a long distance to join us. In looking over the attendance list I noticed that almost all of the engineer divisions and most of the engineer districts have representatives at this symposium. The facilities engineering offices of several military installations are here and we also have representatives from other federal agencies (USGS, NASA, and NOAA), educational institutions, and private industry. Finally, I want to offer a special welcome to our participants from France. It is particularly significant that we have representatives from that country since modern day remote sensing probably can be said to have its beginning from the mid nineteenth century experience of the French military engineer with balloon mounted cameras for mapping purposes. Representatives from most of the offices that I mentioned will be presenting papers during the technical sessions or have prepared exhibits for you to examine during the poster sessions. This broad cross-section of participation, both public and private, speaks well of the general interest in remote sensing and also insures a worthwhile opportunity for the exchange of ideas and experiences.

General Robinson will describe the structure and intent of the symposium in detail in his overview later this morning; however, I would like to touch briefly on the underlying philosophy and theme of these proceedings. The philosophy is the here and now: current technology and applications. The theme is user orientation: technology is of little value unless it is used. Our hopes are that you, the managers of various programs, will leave this symposium with a good understanding and appreciation of what capabilities exist and what other managers are already doing with remote sensing. This may help in your future planning and decision making.

The Engineer Topographic Laboratories has been designated as the principal laboratory for the Civil Works Remote Sensing Program of the Corps of Engineers. As the principal laboratory, we have a management and overseer's role in the research and development being conducted throughout the Corps. Remote sensing is also an integral part of our research in the military topographic programs. ETL is therefore in a unique position to bridge the needs and technologies in the civil and military sector. It is in this regard that ETL is happy to have been able to assist the Civil Works Directorate of OCE in organizing this symposium.

When we began our planning activities almost a year ago, I was concerned that we might have difficulties finding sufficient interest for a three-day conference. I am very pleased that we have had such a tremendous response not only from persons interested in preparing papers and exhibits, but also from the large number of attendees. The sessions have been arranged to present not only up-to-date information about collection systems and data reduction systems for exploiting and processing data, but also to discuss the large number of uses which have been made of remote sensing capabilities. The variety and extent of usage, I think, will be impressive to you. I want to particularly call to your attention the periods on the schedule which have been devoted to the exhibits or poster presentations. These will be demonstrations and/or exhibits of how various agencies have made use of remote sensing in accomplishing project requirements. Most of these exhibits will have project personnel in attendance to discuss their work and to answer your questions. We hope you will take advantage of these sessions to explore more fully how remote sensing has assisted governmental, educational, and commercial organizations and to assess how it may be used in accomplishing your particular mission.

We at ETL are especially interested in your future needs which may require new R&D initiatives or how we may be able to help you with technical advice and assistance to use the existing remote sensing capabilities.

Again, I welcome all of you. I hope you enjoy your stay in the Washington area. If I or my staff can be of any help while you are here or any time in the future, we stand ready to assist you.

KEYNOTE ADDRESS - U.S. CIVIL SPACE POLICY

Dr. A. C. Morrissey
Executive Office of the President
Office of Science and Technology Policy
Washington, D.C. 20500

Dr. Morrissey is a Senior Policy Analyst for the President on scientific and technological issues including, but not limited to, the national security, technology transfer, technology in international affairs, space affairs, and budget matters. He is an architect and principal drafter of Presidential Review Memorandum on the control of U.S. tecynology and the interdepartmental reviews requested by the President on space policy. His previous experience includes the Department of State where he was a Senior Political-Military-Scientific Officer and the Central Intelligence Agency where he was Branch Chief of a multi-disciplinary staff that analyzes China's technological developments. Dr. Morrissey received his Ph.D. in physical chemistry from the University of South Carolina, Columbia, South Carolina in 1967 and a BA in 1963 from Washington and Jefferson College.

Thank you. It's a pleasure to speak today at this Remote Sensing Symposium. I hope to share insight of the broad policy directions that this administration has undertaken in the last several years. In large measure it relates directly to considerations that you are engaged with during this symposium.

Over the past year the Executive Branch has completed two major space policy reviews. During these reviews remote sensing issues were central. I would like to highlight today what these initiatives have been. I think on completion you will agree that the broad initiatives in remote sensing and your objectives are coincident, in that, remote sensing has matured as a tool to meet Corps requirements. I don't need to belabor a discussion of what space has become to our everyday lives. But I think it's important at the outset of any discussion to remind ourselves where we are in space activities. We rely on space systems without even recognizing it. Satellites have revolutionized global communications. Space satellites have provided a new window into predicting our weather. Satellites today give us a whole new range of opportunities to efficiently manage our natural resources, both renewable and nonrenewable. Our reliance on space will continue to grow as we meet our national goals. We are driven to more dependence on space systems for a variety of reasons. Ground based alternatives are often denied by budget, technology, geographics, or political factors. At the same time, it's fair to recognize that space can't be treated uniquely. Space is only an extension of our environment to meet our national goals.

President Carter set the stage, I think, for the U.S. space policy during his speech at the Kennedy Space Center last October. He said, "We have invested some 100 billion dollars in space over the years. It is now time to capitalize on that major investment. The first great era of space is over and the second is about to begin. It will come into its own with the space Shuttle, the heart of our new space transportation system." He went on to say, paradoxically, that the space Shuttle will make the use of space routine in the future and perhaps not as exciting as it has been in the past. As we enter this new era of space it is essential to respond to the new demands as well as its opportunities. We are doing this through a new space policy. The operational character of space broadens the perspective, however, from which we view space. We must address not only the civil activities but the national security programs as well. President Carter acknowledged this when he said, "We must take into account that photoreconnaissance satellites make an immense contribution to the security of all nations. Their use for monitoring arms control agreements is an important stabilizing factor in world affairs." The Carter Administration has given considerable attention to developing our space policy. In fact, perhaps more than any previous administration. The framework for the national space policy was set in May 1978. Many of the broad policies stated by five previous administrations were reaffirmed. Coherent space policy and principles were established. On completion of this national space policy review, the President directed a specific focus on civil programs. It provided the basis for our civil space policy. President Carter's speech at the Kennedy Space Center last fall reflected this outcome.

Our new space policy is designed to carry us successfully into this next era of space. It intentionally is a balanced strategy of applications, science and technology development. It's essential to have these three components and to maintain a balance between them. That strategy will emphasize space applications that will bring important benefits to our understanding of earth resources, weather, pollution, and agriculture; thereby increasing the benefit of the nation's investment in space. It will emphasize exploration in a manner that retains the challenge and excitement of the past and at the same time maintain a vitalized space technology base. Our present exploration program is an excellent one, our future program will maintain our position as world leader. Since much of our leadership depends upon the space Shuttle, we will maintain its development schedule. This has been demonstrated by recent supplemental and budget amendments to maintain steady development progress.

The United States had derived, and will continue to derive, many benefits from space applications; in the area of national defense, foreign and domestic policy, and for the economy. I think it's fair to walk through some of these activities to remind ourselves of our capabilities.

Remote sensing has contributed to our national security, as I mentioned before, assessing and managing our resources (energy, food, and conservation), improving weather and other environmental forecasts, and enhancing our scientific understanding of earth on a global basis. Remote sensing promotes international cooperation and stability. The United States has pioneered the development of remote sensing applications.

Today I would like to address remote sensing from three perspectives. First, over land; second, the atmosphere; and third, over the ocean. First; land programs, of which I am sure your are familiar. The U.S. operates two observing satellite systems for different purposes, a national security effort and the open civil LANDSAT program. The classified effort is designed to support national security needs. This administration, however, has encouraged wider application of space technology and data across sectors to maximize the benefit from the dollar invested. Multispectral LANDSAT data is the only satellite imagery now routinely available for general use. In 1972 NASA launched the first experimental remote sensing R&D satellite. The LANDSAT program has proven the value of multispectral data from space. LANDSAT-D approved for launch in 1981 has programmed life through 1984. The LANDSAT-D-Prime is planned as a backup and could extend data through 1985. The domestic applications of LANDSAT include: First, this symposiumaddresses many of Corps applications. Second, the Department of Agriculture, NASA, Commerce, and AID are engaged in a joint research initiative using LANDSAT and other remote sensing data to monitor crop conditions and provide production forecasts. This is an extension or follow-on to LACIE activities. Discussions after one year about this operation show very, very encouraging signs. Third, Interior is using data for small scale mapping, exploration for minerals and fuels, inventories of irrigated land and hydrological surveys. Fourth, the Department of Energy is exploring the potential contribution of LANDSAT data for energy policy and planning including energy exploitation, powerplant siting, and environmental monitoring. Fifth, many states are using data for planning and management of their natural resources, in demonstration projects, in land cover, surface water inventory, and flood control mapping. In addition, the United States has continued to make data acquired from LANDSAT satellites openly available to the international sphere and has encouraged foreign countries, particularly developing states, to use satellite remote sensing techniques for developmental purposes. An interesting aspect of space technology in the developmental sense is that it's an opportunity to use high technology and not replace a given technology. LANDSAT efforts in the developmental sense have contributed towards that end. Presently there are more than 100 countries purchasing LANDSAT data. Foreign funded LANDSAT receiving stations have been built in Canada, Brazil, Sweden, Italy, Iran, and Japan. Others are under construction in Argentina, Australia, and India. Eight other countries have indicated their intention to establish such stations. AID is working with the French and the Canadians to establish two regional LANDSAT training centers. They also plan to support further centers in Asia and in Latin America. As demonstrated by increasing domestic and foreign use, LANDSAT has generated considerable interest. The private sector involvement in remote sensing, especially in the oil and mineral industries, has been evidenced through their interest in LANDSAT and other follow-on satellite capabilities such as STEREOSAT.

This administration has made a commitment of the continuity of remote sensing data through the 1980s and ultimately to an operational remote sensing system. This is a significant step; the first time an administration has gone on record indicating its intentions to go operational with a civil/land operational program. The technology mix will evolve over the next several years. In large part, two interagency task force reviews which are nearing final completion provide the background for this direction. First, the President directed last fall that a comprehensive plan covering technical programmatic and institutional arrangements be developed. NASA chaired an interagency task force with emphasis on user agency requirements to examine options for integrating current and future potential systems into an integrated, national system. One of the participants is in the audience today; Dr. Cehelsky was heavily involved in that effort from NASA. Second, the administration has encouraged entry of the commercial-private sector into remote sensing applications. NASA and the Department of Commerce co-chaired an effort to examine how to encourage private investment, direct participation, in an operational civil remote sensing system. The Corps of Engineers participated in that review. As a result of the private sector examination, it appears at this time the private sector is not ready to take on a significant role in remote sensing without significant subsidy.

Next, I'd like to talk briefly about atmospheric programs. As you know, the U.S. is a worldwide leader in meteorological satellite systems and launched our first satellite in 1960. The data are provided throughout the United States and to over 70 foreign countries that have direct readout facilities. In parallel activity the Defense Department operates the Defense Meteorological Satellite Program (DMSP). Direct readout is now provided to operational military commands at land and sea. The current operational systems are scheduled to continue with improvements as they are necessary. This administration has examined the question of whether additional convergence of civil and defense programs is warranted. We are examining whether future cost savings, as well as efficiencies, are possible.

Finally, I would like to talk of ocean programs. In mid-1978, NASA launched SEASAT I, the remote sensing R&D satellite dedicated to observing characteristics of the ocean. Wave characteristics, ocean surface temperature, and sea-ice dynamics could be derived from SEASAT observation. Such data could contribute to improved ship routing and coastal disaster warning. Moreover, ocean current patterns and temperatures could be used in fishing, pollution dispersion, iceberg hazard avoidance, and global climate studies. Several federal agencies, and I notice the Corps, have funded or are working with SEASAT data. While SEASAT I was acquired for only a short period of time, benefits were verified. Large scale ocean observations which are the needs of the Defense Department, the Commerce Department, and others might be met from integrated oceanic satellite systems. This administration supports an integrated approach in principle, whether and how to proceed still remains under review. Likely some of you are aware of the concept called the National Oceanic Satellite System. It would serve the requirements of both the military and civil sector from a common platform.

Integrated remote sensing systems have an opportunity to prosper. Until now the civil space programs for observation of the ocean, weather, and land have been conducted separately. There are new developments, however, that make the establishment of an integrated national system for observing the earth worthy of consideration. First, the array of sensors now emerging for the observation of the atmosphere, land, and ocean and the examination of data needs indicate that a select group of several sensors on a limited number of common platforms could meet a large number of requirements. Second, the Shuttle, and the new opportunities, makes it possible to combine sensors on a given platform on an economical basis without effecting reliability. Third, remote sensing has demonstrated its potential for a variety of applications. We must now proceed to devise institutional arrangements to provide users continuity of data. Finally, the global and political nature of remote sensing from space requires proper institutional focus, government authorization and regulation. As a consequence of these developments and the desire to maintain American leadership in space technology, the President directed NASA to chair this interagency task force on options for integrating current and future potential systems into an integrated national system that I mentioned earlier. This review is nearly complete and decisions are imminent. We examined organizational arrangements; a new agency concept, joint multi-agency approach, or the concept of a lead agency. The four agencies examined, as taking an operational responsibility, were NASA, Commerce, Interior, and Agriculture. (See attached Presidential Statement.)

In sum, the future for remote sensing is bright. As we enter the 80s our approach on a national program will be transformed by the advent of the Shuttle moving us into an era of routine work in space. Actually, this transformation will be as historic as man's first landing on the moon. As space becomes an extension of our working environment, we can expect more and more nations to want to share in the benefits. This country is well prepared to meet the challenges and competition ahead and the opportunities for cooperation. We go forward with considerable confidence. The Carter Administration space policy provides a framework for a strong and evolutionary program. We will build on the Shuttle and on our other capabilities. We will continue to share our space capabilities for the benefit of all people. But, as President Carter said in October 1978, "We will begin to encourage other nations to participate in the work of space and its benefits but we will not give up leadership of the United States in space." Thank you.

ATTACHMENT

OFFICE OF THE WHITE HOUSE PRESS RELEASE
November 20, 1979

THE WHITE HOUSE

The President today announced the designation of the Commerce Department's National Oceanic and Atmospheric Administration (NOAA) to manage all operational civilian remote sensing activities from space. This designation is one of several policy decisions announced today after a review of civilian space policy mandated by a Presidential Directive in October, 1978.

Early in his administration, the President directed a comprehensive review of space policy. The review, completed in May, 1978, resulted in a Presidential Directive that established a national space policy framework. It created a Policy Review Committee on Space, chaired by the Director of the Office of Science and Technology Policy, Frank Press. One of the tasks of the Policy Review Committee has been to assess the Nation's future civil space remote sensing requirements. That review was the basis for the policy decisions announced today.

Designation of a single agency, NOAA, to manage all civil operational satellite activities will lend itself to further integration and potential cost saving in the future. NOAA's experience in successfully operating and managing three generations of weather satellites prepares it to assume the responsibility for land remote sensing in addition to its ongoing atmospheric and oceanic activities. NOAA's first action will be to develop a transition plan in coordination with other appropriate agencies for moving to a fully integrated satellite-based land remote sensing program.

Initially, our operational land remote sensing efforts will rely on experience derived from the LANDSAT program. LANDSAT was begun in 1972 by NASA as a satellite effort specifically designed to observe surface features of the earth.

The President's decision establishes a three-part framework to serve remote sensing activities:

- -- Integration of civilian operational activities under NOAA.
- -- Joint or coordinated civil/military activities where both parties' objectives can be best met through this approach.
- -- Separate defense activities which have no civilian counterpart.

Other space policy decisions developed by this review and announced today are:

-- The Commerce Department will seek ways to further private sector opportunities in civil land remote sensing activities, through joint ventures with industry, a quasi-government corporation, leasing, etc., with the goal of eventual operation of these activities by the private sector.

-- We will continue the policy of providing LANDSAT data to foreign users, and promoting development of complementary and cooperative nationally operated satellite systems so as to increase benefits for all nations.

-- The Department of Commerce will establish and chair a Program Board for continuing federal coordination and regulation of civil remote sensing activities. The involved federal organizations will be represented (i.e., the Departments of Defense, Interior, Agriculture, State, Transportation, and Energy, and NASA, CIA, AID, and EPA). The National Governors' Association and the National Conference of State Legislatures will be invited to participate.

-- Separate weather program for the military and civil sectors will be maintained under the Departments of Defense and Commerce because of their differing needs. We will continue procurement of current spacecraft until development of a new system design is justified. Future polar orbiting satellite development and procurement will be jointly undertaken by Defense, Commerce and NASA to maximize technology-sharing and minimize cost.

-- Ocean observations from space can meet common civil and military data requirements. Accordingly, if we decide to develop ocean satellites, joint Defense/Commerce/NASA management of the program will be pursued.

# # #

(For further information on the above, contact the Office of Science and Technology Policy (Art Morrissey/395-5736) or the Department of Commerce -- NOAA (George Benton/377-5938 or David Johnson/763-7190.))

SYMPOSIUM OVERVIEW

BG H. G. Robinson
Deputy Director, Civil Works
Office, Chief of Engineers

This article is a condensation of Brigadier General H. G. Robinson's Symposium Overview address at the U.S. Army Corps of Engineers Remote Sensing Symposium held at the Sheraton International Conference Center, Reston, Virginia, on 29-31 October 1979. General Robinson is the Deputy Director of Civil Works, Office of the Chief of Engineers.

He is a 1954 graduate of the U.S. Military Academy at West Point and has been an engineer officer throughout his 24 years of commissioned service holding positions of increasing responsibility both as an Army commander and district engineer, Los Angeles, California.

General Robinson has a Master of Science degree in Civil Engineering from the Massachusetts Institute of Technology. He is a member of the Association United States Army and the Society American Military Engineers. He has served in Vietnam as an executive officer of the 45th Engineer Group and as commander of the 39th Engineer Combat Battalion. Among his decorations, he holds the Legion of Merit and Bronze Star with Oak Leaf Clusters.

General Robinson expressed his pleasure in attending and participating in the Remote Sensing Symposium as he was extremely interested in the subject. "I have become involved in the fringes since I've been in Civil Works. I hope that I can move that fringe involvement closer to the center of the Corps at some point," he said.

"The Corps has achieved many successes with satellites and the entire spectrum of remote sensing technology," General Robinson said. He made the following points during his address:

a. As early as 1940, the Corps used aerial imagery to investigate shoreline problems.

b. During the last 12-15 years the Corps' use has escalated with increased concern for environmental effects and added emphasis on multipurpose planning.

c. The Corps' involvement with LANDSAT began in June of 1971 when the Civil Works Directorate participated in a National Aeronautics and Space Council Study to evaluate the usefulness of remote sensing information obtained from aircraft and space craft for improving the management of our environment and our resources. This study initiated the Corps' remote sensing program.

d. The first operational demonstration of the usefulness of LANDSAT was in 1973 when the Corps used LANDSAT in coordinating emergency flood-fighting activities in the remote mountainous areas of New England.

General Robinson added, "I have been privileged to be involved in work with NOAA, adapting some of their satellite activities to provide us with real time type readouts during flooding situations and increasing the capabilities of their equipment so that we can get more rapid readings during the time when we really need them - during the flood emergency itself.

"In the next decade, pressures on the environment will not decrease. Instead, they will increase as the population increases and the natural resources -- especially water -- dwindle," he said. "It is, therefore, very important that we continually improve our technology in remote sensing so that there is minimal environmental impact as we work to carefully manage our water and other non-renewable resources.

"We've come a long way with remote sensing techniques -- and the data from these systems have made significant contributions to many of our Civil Works activities and responsibilities."

General Robinson cited the following examples:

a. Planning and Design of Water Resources Projects - Remote sensing has been a tool for studies to determine the extent of the drainage areas that we are looking at and how those areas will drain.

b. National Dam Safety Program and Dam Inventory - Use of LANDSAT is helping us meet our January 1980 inventory completion date. Over 55,000 dams are in the inventory. LANDSAT assisted this program by locating water bodies. Dam location was then verified by on-ground reconnaissance and the safety inspection itself.

c. Identification and Monitoring of Wetlands - Remote sensing helps us meet our regulatory responsibilities in the permit program and in wetlands mapping which would take 4-5 years using conventional high-altitude photography. "We've been working very closely with the Fish and Wildlife Service in their wetlands inventory. They've used some of the LANDSAT data that we've developed in our program. No one is going to obtain the data faster than we have through LANDSAT. As the data and system become more refined, I believe LANDSAT can be the answer as far as our regulatory program is concerned. In the meantime, the Fish and Wildlife Service is developing a more detailed identification and mapping system," General Robinson said.

d. Coastal Protection - Seasat collected data on wind speed, wave height, currents, and other meteorological conditions. Reflecting his experience as district engineer in Los Angeles, General Robinson emphasized again, "You can't monitor the entire coast any other way than satellite reconnaissance. It's been a great help to the state of California and other areas of the nation in providing needed bench marks and the opportunity to view the changes that are occurring along our coastline. Our coastline is not as stationary as many of us like to view it -- it's moving in and out all the time. You need a rapid means of identification of the types of movements taking place and their causes."

e. Flood Control Forecasting, Flood Plain Management, Flood Damage Assessment - LANDSAT has been of immeasurable help in these areas.

f. Environmental and Ecological Assessments - Remote sensing provides near-real time observation and communication of environmental conditions and also provides assessment and mapping of existing physical conditions to detect and monitor changes in those conditions. "It's very important that we're able to do this," said General Robinson. "Otherwise, people who wished to circumvent our permit program could complete a project and have it on line before we were even aware that it was underway, especially in remote areas. This gives us an opportunity to establish that base, to look at the changes that are occurring, to find the violators, and to find those who have attempted to evade the system through their own means."

g. Regional Geographic and Geological Studies - Surface bedrock mapping, faults that may indicate potential earthquake activity --- again, LANDSAT can be of assistance in this area.

h. Hydrologic Research - The NOAA satellite GOES program (Geostationary Operational Environmental Satellite) collects hydrologic information on river stage, moisture data, and precipitation data, to name a few. We are interlocking with that program to assist us in our engineering area. In all of these areas the key is the speed with which the information can be made available and the relatively small cost compared to other means of obtaining the same information.

General Robinson stated that the remote sensing seminar program will present and discuss many techniques and demonstration projects which he thought were important for the attendees to consider as doers, managers in the field. He emphasized the adaption of these techniques to meet the needs of the people in the field -- techniques such as data collection, photogrammetry, photo interpretation and image data processing, information extraction, and future satellite systems.

"The successes that we've had with the program have meant a great deal to our mission accomplishment, but even our failures have provided valuable knowledge for future systems," he said. "One of the pitfalls that we must avoid in adapting remote sensing, LANDSAT, and other techniques to our current everyday programs, is what I call the institutional obstacles. As you continue to perform your daily tasks the opportunity for change may sometimes escape you, because you're all very busy and involved with everyday problems. Sometimes you have to invest a little effort to take advantage of what technology can give us. Effort which may, at the time, seem ill-advised for your investment. Like other new systems we put on line, it takes a little time to get used to them working properly. But, I submit to you that the investment of that time is well worth the potential for achievement that you will experience later and, as a by-product, the reduction of time that you have to spend completing the same job."

General Robinson concluded, "We've heard a great deal of discussion on what remote sensing can do. I think this is one of the first symposiums -- if not the first -- which focuses on what is being accomplished today, and what is available in the technology bank today. This focus will help you to move us down the road towards greater achievement, greater accomplishments, and better service to the people of this nation. This is our job. The technical papers that will be presented in the next three days will describe the techniques and the ways we can use the technology. Each technical session will be followed by poster sessions highlighting the applications which show how the technology has been used.

"I think it's important to realize that together with USGS, NOAA, and NASA, the success of our systems and the success of this symposium depends on you - each of you. Your active participation in the discussions and your questioning approach -- asking what each system can do for you, what you need, what you require -- are needed to ensure that we are not embarking on a road of useless technology and another stack of papers which just accumulate and accomplish nothing," he said. "So, I entreat you to spend your time wisely at this symposium and to ask questions. That kind of questioning perspective from the field is so important to the success of the technology transfer of any of our processes."

HIGH ALTITUDE PHOTOGRAPHY AND COASTAL ZONE MAPPING

Allan C. Bock

Mark Hurd Aerial Surveys, Inc.
Minneapolis, Minnesota

Mr. Chairman, Ladies and Gentlemen:

All of the references up to this time have dealt with remote sensing from satellites. Now I'm going to have to ask you to come down out of the stratosphere to the level that airplanes fly at. After all, aircraft are the real work horses of the remote sensing profession.

The subject of my paper is high altitude photography, but I am going to take the liberty of combining this subject with related subjects which I believe will be of interest to the Corps. These are wetlands mapping, coastal zone photography and tidelands mapping in the State of New Jersey.

Returning to the subject of aerial photography, I would like to emphasize that the acquisition of precise aerial photography at any altitude embraces skills that are not taught in any school or university that I am aware of. The efficient acquisition of precise aerial photography comes only from long, concentrated experience working to precise specifications.

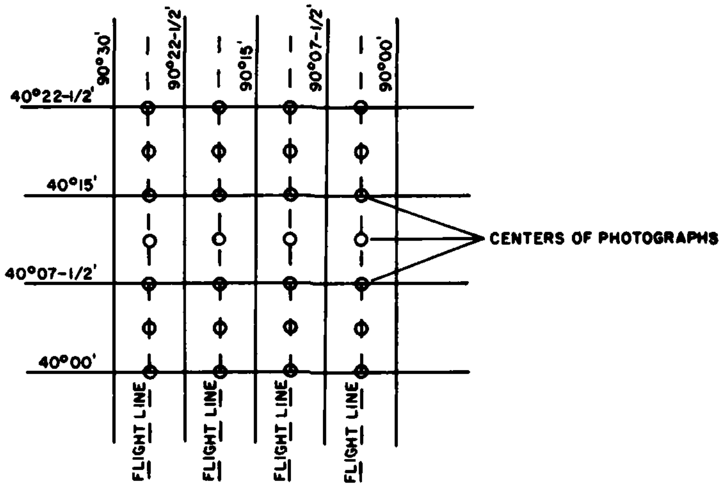
I stress the word precise because anyone can go up in an airplane and take pictures, but the value of those photographs is commensurate with the precision of the placement of the photographs and the quality of their geometry and imagery. The Air Force and NASA perform aerial photography, but I suggest that if you need consistently precise high quality photography, those are not the best sources. The Air Force, of course, must maintain a photographic capability for military purposes. NASA's attempt to maintain this capability is, in my opinion, another wasteful attempt to expand a bureaucracy into a field which is already expertly served by the private sector.

As we reach higher and higher altitudes, we are entering a new environment which embraces a science which has not yet been named. This science is a combination of aeronautical engineering, mechanical engineering, electronic engineering, optics, photography, piloting, photogrammetry and civil engineering. It comes under the broad heading of remote sensing, but like the term "engineering" it needs more specific identification.

Over the past 30 years our company has developed a sizable reservoir of experience and skill in these areas. Our indoctrination into high altitude photography started in 1948 with Lockheed P-38 and Boeing B-17 aircraft which we operated up to 39,000 feet.

With the advent of the small business jets, we developed and patented a camera door for the Learjet and have since used it very successfully in Central and South America, Africa, Greenland and the United States, including Alaska. Perhaps the most effective use of the Lear has been in the U. S. Geological Survey quadrangle mapping program. For this program the flight lines are designed North-South, and are located in the exact center of each tier of 7-1/2 minute quadrangles.

Flying at 40,000 feet, photographs are then spotted at the center of each quad and on the north and south edge of each quad. Perhaps an illustration will clarify this.



The photographs must be spotted very precisely in order to accomplish their purpose. The specification requires that the center of the photograph be within 2,000 feet of a predetermined position, and that the aircraft be within 2,000 feet of a predetermined true altitude above terrain. That's true altitude, not pressure altitude.

When designed in this manner, the photograph spotted in the center of the quad will cover the entire quad and can be used to make controlled enlargements of that quad, which in flat country results in a very precise ortho map. In rough country, stereo models covering the entire quad can be set up using the center photo and the photo on each side. From these models orthophotos can be produced, and contours and planimetry can be drawn.

We have completed this type of photo coverage for many states, as well as USGS, and delivered controlled half-tone transparencies at scales of 1:24,000 and 1:12,000 from which any state agency can run prints in-house on their own ozalid machine of any part of their state. They use these prints for planning and for updating existing maps. With the use of an overhead projector they can enlarge the transparencies to 1:6,000 for detailed study of relatively small areas. Without exception they have been enthusiastic about this program and usually wear out their transparencies in a very few years.

We photographed New Jersey, Florida and Colorado in this manner, using color infrared film. By making black and white internegatives from this film, we were able to produce enlargements containing an abundance of detail which would otherwise be lost in black and white photography. This is because infrared photography registers detail which black and white fails to record. In addition, the infrared film transparencies are available to geologists, foresters and environmental agencies for a large range of studies.

The New Jersey wetlands mapping began with a test project in 1971, which consists of two areas. One in the Tuckerton area representing a coastal or salt water area, and the other near Salem representing inland or fresh to brackish water.

Existing geodetic control, both federal and state, were targeted prior to flying, and three types of film were exposed simultaneously, namely panchromatic, IRC and natural color at 1:12,000 scale.

In addition, a special flight was made using black and white IR at various tide levels. The rest consisted of making maps at both 1:6,000 and 1:2,400 scale in order to determine the scale most suitable.

Before the test was completed, it became obvious that simultaneous infrared color and natural color gave the best results, and consequently the main wetlands mapping project began in the summer of 1971. Photography was obtained for the entire coastal area from the Raritan River to Trenton. Photography was obtained using two cameras simultaneously, one using IRC film and the other natural color film. Photography was obtained at a scale of 1:12,000 with six-inch cameras.

Photography was spotted to fit predetermined sheets 6,000 feet east-west by 7,000 feet north-south. Exposure was made at the center of each sheet and at the north and south edges, similar to quadrangle spotted photography. This provided a forward lap of about 60% and a little over 30% sidelap. Consequently, the photography was suitable for photogrammetric aerial triangulation.

Photography also was obtained with panchromatic film at 1:30,000 in strips along the coast designed to take advantage of the existing ground control as much as possible.

As I stated above, prior to flying, sufficient existing ground control points were targeted to provide control for aerial triangulation. These consisted of available USC and GS, USGS and New Jersey geodetic control. Using this control and the 1:30,000 scale photography, an aerial triangulation solution was done to tie the entire network of photography together.

A secondary aerial triangulation solution was done using not only the original targets, but the supplemental points established through the high altitude solution and using the low altitude 1:12,000 photography. This final solution provided state plane coordinates for selected pass points within the wetlands area which for this purpose was designated as all of that area below ten feet of elevation. These coordinated points were then used to rectify the central exposure for each sheet in our SEG V. The plan was designed to guarantee national map accuracy standards of all detail below ten feet of elevation.

Rectified enlargements were made from black and white internegatives produced from the IRC photography and showed all the various shades of gray representing the original shades of red and pink in the IRC photography.

Copies of the enlarged images along with the original IRC and natural color transparencies were furnished to Earthsat who performed the plant species delineation through which they determined the upper wetlands boundary. This boundary is the highest level affected by the salt water as determined by plant species.

The species lines were drafted on a preprinted border plate, along with names data and two grid systems (UTM and state grid), and the latitude and longitude ticks. The overlay was printed in conjunction with the screened image to produce a reproducible film positive of the completed base map.

An additional overlay was prepared from existing tax maps to indicate the property lines throughout the wetlands area. This was produced as a clear base overlay keyed to the base map, along with a list of property owners keyed to the overlay. A total of approximately 900 wetland maps were produced in this manner.

COASTAL ZONE PHOTOGRAPHY

The wetlands maps were prepared as a regulatory medium. That is, the area below the upper wetlands boundry was henceforth to be controlled by the state, and no construction activity was to take place in this area without the permission of the Department of Environmental Protection (DEP). By law they were assigned the task of not only mapping the wetlands area, but monitoring it to see that no violations occurred. Therefore, in September 1973, we were contracted to obtain a flight along the coast for the initial monitoring flight, which I believe was as soon after the 19th of September as possible. This photography was obtained at a scale of 1:35,000 using IRC film, which was deemed adequate to use for comparison with later imagery to determine if violations had taken place.

TIDELANDS MAPPING

In order to determine the proper approach, a test was performed in the Hackensack Meadows and Newark-Elizabeth area in 1972. For the Newark-Elizabeth area, the 1:80,000 scale imagery was used. It was rectified and enlarged to USGS quadrangles and produced at a scale of 1:9,600 as a single sheet.

The Hackensack area was flown at a scale of 1:12,000 using the same technique as described above for the wetlands map and consisted of 36 sheets. For each of these tests, claims overlays were prepared jointly by MARKHURD and DEP. DEP indicated the sources and lines they wanted to use, and MARKHURD made the necessary transfers by enlarging and fitting old map sources and photography to the base map. Some of these materials were used in court cases in New Jersey, the State winning their point.

The purpose of the claims overlay was to indicate the limit of the area "now or formerly flowed by high tide." The area below this was the area that the State claimed was their property.

Before the test was actually completed, the main tidelands mapping was initiated, with photography taken in 1977 and 1978. The entire coastal area up to 20 feet elevation was photographed in a manner similar to that described for the wetlands mapping. Additional ground points had to be targeted, and an additional high altitude panchromatic flight had to be obtained in order to cover the additional area reaching inland.

The constraints for flying were much more rigid for this than the previous flying. The main requirement was that photography be obtained no closer than one hour of high tide. This required a very careful study to lay out the entire area by zones. Using predicted tide information published by the NOS and supplemented by information furnished by the Office of Environmental Analysis, we established the hours between which photography could be obtained and maintain the tide restriction. Using input data to a computer program, a machine tabulation was made for each day from the beginning of the flying season until the end, showing the time to the nearest 15 minutes when photography could be obtained for each zone.

In addition, the tabulation indicated the time for each day when photography could not be obtained in the vicinity of noon when the sun angle was so high that it would introduce sun spots in the water areas in the corners of the photographs. At the beginning of the season this period was approximately two hours. Toward the end of the season it disappeared completely.

Using control developed for the wetlands project, supplemented by additional aerotriangulation and new target points, aerial triangulation was performed to establish control for rectification and positioning of the new image and producing up-to-date maps where they were previously prepared, as well as new maps where they had not been prepared. The total area was covered by approximately 1,475 sheets excluding the 36 sheets in Hackensack and the Newark-Elizabeth area. This new project covers the entire coastal area from the Hudson River at New York around Cape May up to Trenton.

This project includes the stage of preparing intermediate products consisting of rectified historical photography and enlarged historical maps. The historical photography consists primarily of 1:20,000 scale photography obtained in preceding years beginning about 1940. This photography is being rectified to fit the base maps so that the old water courses can be placed onto an overlay in their proper position. The enlarged historical maps are being used in the same manner, some dating back to the 1880's.

Once OEA has made their interpretation and furnished the necessary instructions, MARKHURD prepares these claims overlays keyed to the base maps.

We also have performed a wetlands survey of the coast of Long Island for the State of New York in much the same manner as the New Jersey wetlands project.

In closing, I can say that we believe most of the world's coastal zones and inland wetlands will eventually be mapped in much the same manner.

A very large part of the credit for developing this method and the procedures goes to Mr. Roland Yunghans of the New Jersey Department of Environmental Protection.

-0-

THE COMMERCIAL USE OF RADAR AS A REMOTE SENSOR BY GOVERNMENT AND INDUSTRY

R.K. Peterson

Goodyear Aerospace Corporation
Litchfield Park, Arizona

Mr. R. K. Peterson is a Senior Systems Engineer with Goodyear Aerospace Corporation at Phoenix, Arizona, U.S.A. He presently is assigned to the company's remote sensing department and is responsible for the Goodyear Electronic Mapping System (GEMS™) radar imagery. Mr. Peterson's previous experience includes the design and development of optical radar data processors for coherent radar systems, including the equipment now utilized by the GEMS radar.

Before joining Goodyear, Mr. Peterson was Chief Engineer of Wiley Electronics Company, Phoenix, Arizona. He has a Bachelor of Science degree in physics from the University of Colorado and a Master of Science degree in electrical engineering from the California Institute of Technology.

ABSTRACT

The use of radar as a remote sensor is discussed in general terms. The differences between radar and other remote sensors are described and relationship of radar resolution to Landsat and to conventional cameras is illustrated. A distinction is made between coherent, or synthetic aperture, radar and conventional, or "brute force," radar. The differences in performance and usability of the two types of radar are discussed.

Examples of radar imagery, including radar mosaics, and enlargements up to 1:50,000 scale imagery are presented. The use of these images for the preparation of charts of land use, geology, geomorphology, soils surveys, and other applications is illustrated. Some examples of forest evaluation, soils recognition, and geological analysis also are given.

Multiple imaging techniques are discussed and examples of polarization diversification and radar stereo are shown.

1. INTRODUCTION

The preparation of long range plans for the exploitation and continuing use of the land surface and its subterranean resources is now a high priority task in most countries of the world.

Two serious problems face the planner when he sets out to create a comprehensive strategy for future land use. These are:

1. What are the physical facts pertaining to the land in question?
2. What impacts do these facts have on land use, its longevity, its ecological systems, and the people who occupy it?

It is inherent in the nature of the land use planning problem that the second question cannot be usefully answered until a reasonably definitive answer to the first question is available. It is therefore true that many land use programs are seriously impaired by the lack of raw data concerning the land in question. The last decade has seen an ever increasing effort to collect this raw data by means of remote sensing.

2. RADAR AS A REMOTE SENSOR

Remote sensors are now available in considerable variety, including conventional cameras, infrared sensors, multispectral scanners, magnetometers, radiation detectors, and radars. It can be stated in general that each of these sensors has established itself as a useful tool for the collection of certain kinds of data. The failure of any one method to dominate the field of remote sensing arises from the simple fact that each sensor provides a certain amount of data unique to itself and not usually obtainable from other sensors. This paper will discuss the kinds of data which can be provided by radar.

Radar derives its value from characteristics that distinguish it from all, or nearly all, other sensors.

1. Radar operates in a portion of the electromagnetic spectrum differing from other sensors and, consequently, measures a different characteristic of the terrain
2. Radar operates at a low grazing angle, providing an excellent impression of relief for easy interpretability and often providing unique data from shadowing
3. Radar is among the more accurate sensors from a geometric point of view, providing an excellent mapping tool and a very rapid means of acquiring a synoptic overview
4. Radar is all-weather, permitting operation at times, in places, and under circumstances not otherwise possible

---

NOTE: Because of the limitations of printing, the full quality of the radar images in this paper is not reproduced. Persons desiring copies of specific illustrations should request them from the author at Goodyear Aerospace Corporation, Box 85, Litchfield Park, AZ 85340, U.S.A.

5. Radar acquires imagery in which many geomorphological and geological features are intuitively obvious. Radar imagery is, therefore, one of the most easily interpreted kinds of imagery. This means that unmodified radar mosaics make excellent maps and planning aids for either skilled or unskilled users

6. Radar offers relatively high resolution together with rapid, large-area coverage not available from most other sensors.

The last characteristic is not the least important of those listed. Figure 1 shows the relationship of the resolution of commercial radar to the resolution of other imaging sensors. A Landsat picture element (pixel) is of the order of 70 meters on a side as shown by the large shaded area in the figure. An equivalent radar pixel is less than 10 meters. Photography can provide data with resolution in the less-than-one-meter (or even less-than-one-foot) range. This relationship points out one of the domains where the application of radar is most useful; *i.e.,* where Landsat imagery provides insufficient resolution and photographic mapping is either too expensive or cannot be provided in a useful time frame.

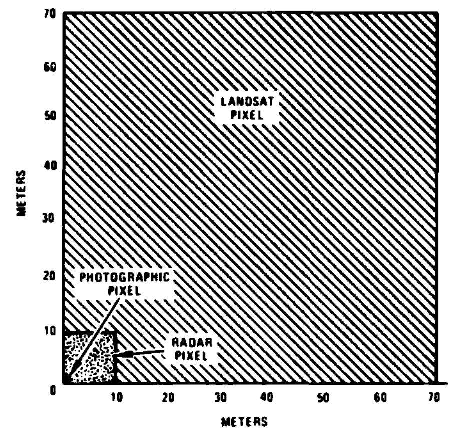


Figure 1 – Relationship of Commercial Radar Resolution to That of Other Imaging Sensors

3. COHERENT RADAR

Radar is different from most remote sensors in that it supplies its own illumination and thus measures a passive surface property of the terrain. Radar measures a characteristic of the terrain called its scatter coefficient. Figure 2(a) illustrates this phenomenon. Signal is returned to the radar only when the area being surveyed is rough and "scatters" energy. Some of this scattered energy is returned to the radar receiver and constitutes the radar signal. Areas of return are called "diffuse" as opposed to those that do not reflect a signal, called "specular."

Figure 2(b) illustrates the fact that the radar return signal varies both as a function of the type of terrain in question and as a function of the radar depression angle. Depression angle, in turn, is a function of the slope of the terrain. It is this latter feature that permits radar to give a visual representation of terrain altitude.

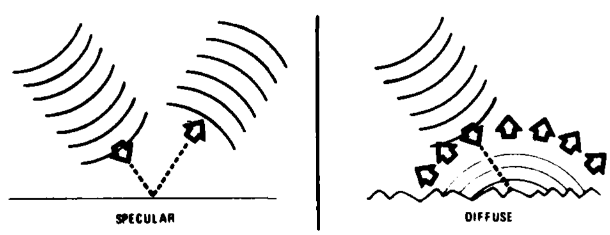


Figure 2(a) – Scatter Coefficient Characteristic of the Terrain

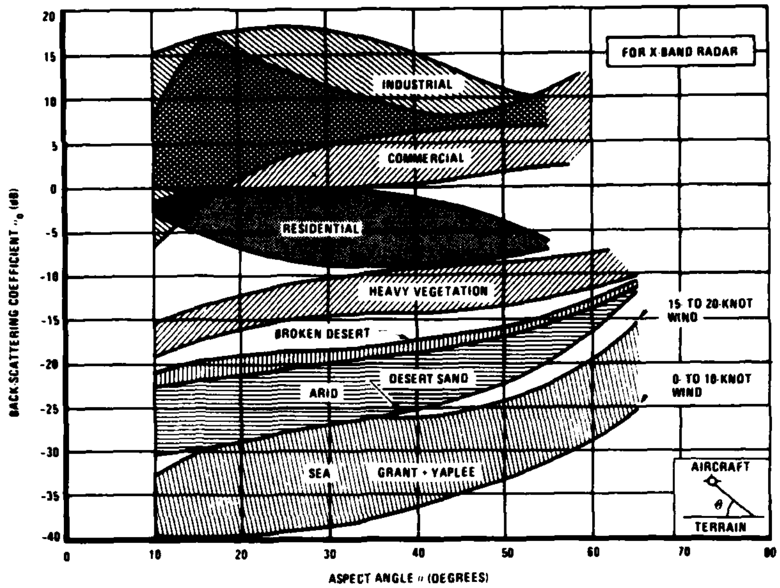


Figure 2(b) – Signal Varies as a Function of Type of Ter ain and Radar Depression Angle

Radar systems available for commercial survey work can be divided into two generic types designated "brute force" or noncoherent radars and coherent, or synthetic-aperture radars. The former type is fairly simple in concept, and it generates an immediate image of the terrain in a manner similar to the conventional radars employed during World War II. This image is recorded on film from the face of a cathode-ray tube and the film is the principal system output. The advantages of the system lie in its simplicity and in the immediate availability of data. Disadvantages of the method are apparent in areas of poorer and uneven resolution, geometric problems, and a fundamental loss of data at the recording point. Figure 3 illustrates the noncoherent brute force system.

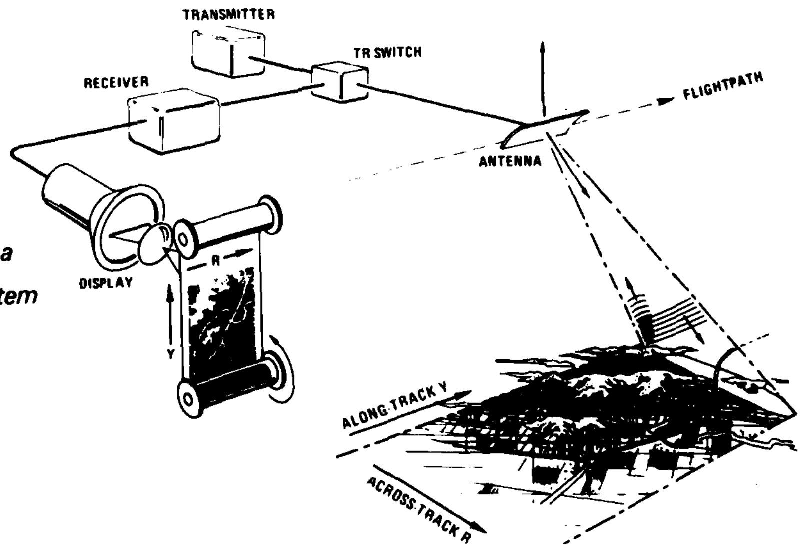


Figure 3 – Example of a Brute Force Radar System

The second type of radar, called a synthetic-aperture radar (SAR), corrects these deficiencies by storing the radar data in the form of a hologram and recreating the image of the terrain in an optical or digital processor. The method offers several unique advantages:

1. Higher and more uniform resolution
2. Improved geometric fidelity
3. An archival data storage that permits the regeneration of original imagery when desired.

The fundamental concept of the synthetic-aperture radar is illustrated in Figure 4.

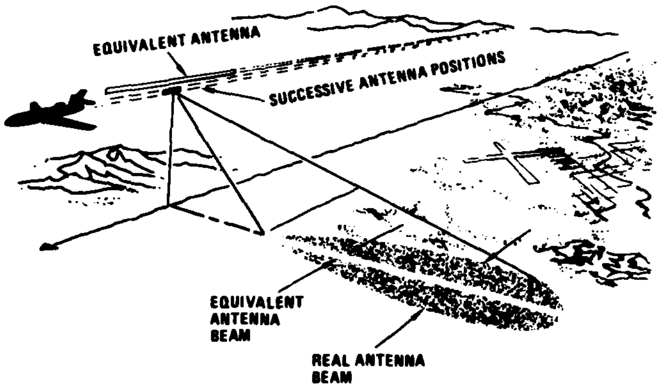


Figure 4 – Fundamental Concept of Synthetic-Aperture Radar

The figure shows a high-altitude vehicle with a small real antenna that illuminates the terrain in the shaded area. As the vehicle moves, the small antenna will assume successive positions along the flightpath as shown by the dotted trail behind the aircraft. Radar data are collected by the system at each of these positions and stored on film. The data are later processed to produce an image of the terrain. The processing has traditionally been accomplished by optical means as illustrated in Figure 5. A strip of film containing the data is illuminated by coherent light and the optical system performs a Fourier transform of the data allowing signal filtering as well as the generation of the desired image. Digital processing of the radar data is also possible and is becoming more widely used as the size and cost of digital elements is progressively reduced. In either case the final image coming from the processor has fine resolution equivalent to that which could be obtained by the very long antenna shown in Figure 4 just above the dotted path. The ground resolution is illustrated by the narrow clear area in the center of the shaded beam pattern.

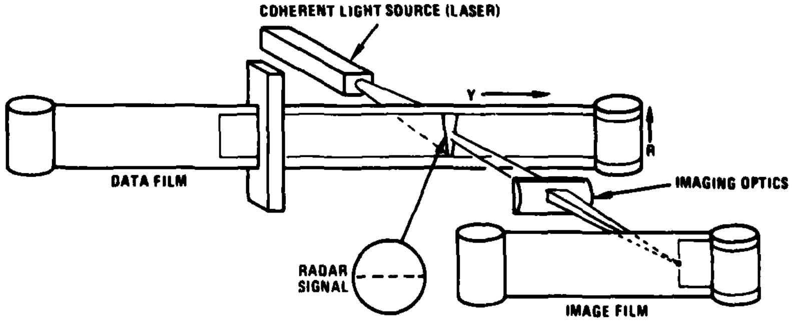


Figure 5 – Synthetic-Aperture Radar Data Processing

4. THE IMAGE PRODUCTS OF RADAR

The immediate end products of a radar survey usually are black and white radar mosaics of the terrain in question. Figure 6 is an example. These mosaics are prepared in map format at a suitable scale, utilizing photographic prints of the original radar negatives. In a high performance, synthetic-aperture system, enlargements of any area can be made available up to scales of 1:50,000. Figure 7 shows an area containing fruit orchards taken from a typical survey. It is important to realize that resolution comparable to this image is available throughout the radar data. While the overview mosaic as illustrated in Figure 6 cannot display the total resolution nor the total dynamic range, suitable enlargements always can be provided directly from the data film or from the original radar correlations. Users of radar survey data should always consider the preparation of such enlargements either as part of the original survey or as a later effort, utilizing the radar negatives and the user's own enlargement and photographic facilities. The high resolution which permits enlargement is particularly valuable in land use studies where the analysis of vegetation and terrain cover is important.

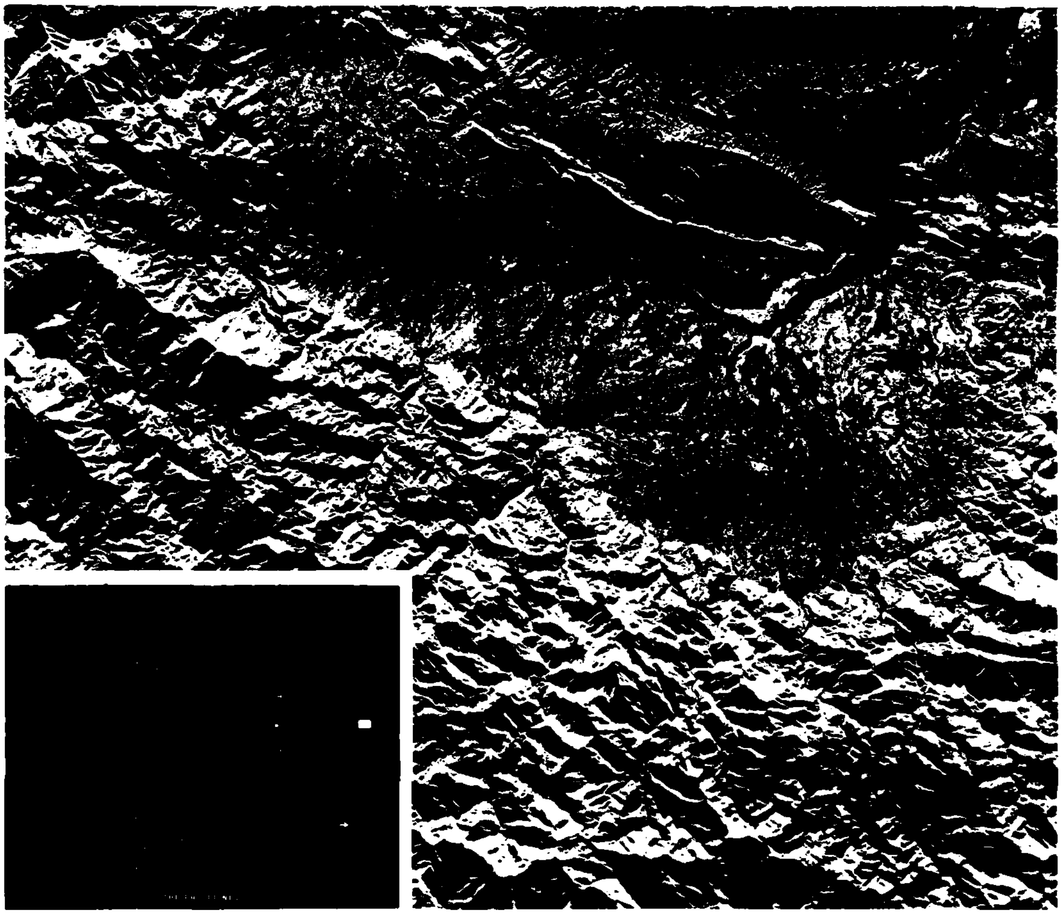


Figure 6 – Example of Radar Mosaic Constructed from Radar Imagery (Philippines)

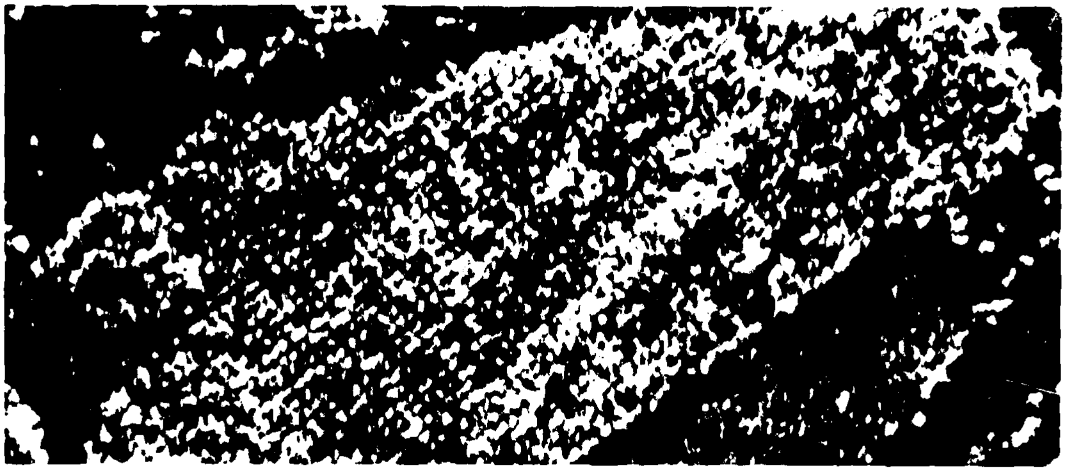


Figure 7 – Enlargement of Area Containing Fruit Orchards (Texas, U.S.A.)

In addition to the radar imagery and radar mosaics, many interpretation products can be obtained by contract from the survey company, or they can be generated by the user. Figure 8 shows a land use chart created by Project RADAM in Brazil. Radar was the primary source of data for the preparation of this chart as well as for charts illustrating geology, geomorphology, phytoecology, and a soils survey. The soils survey chart of the same area is shown in Figure 9.

Figure 8 – Project RADAM Land Use Map

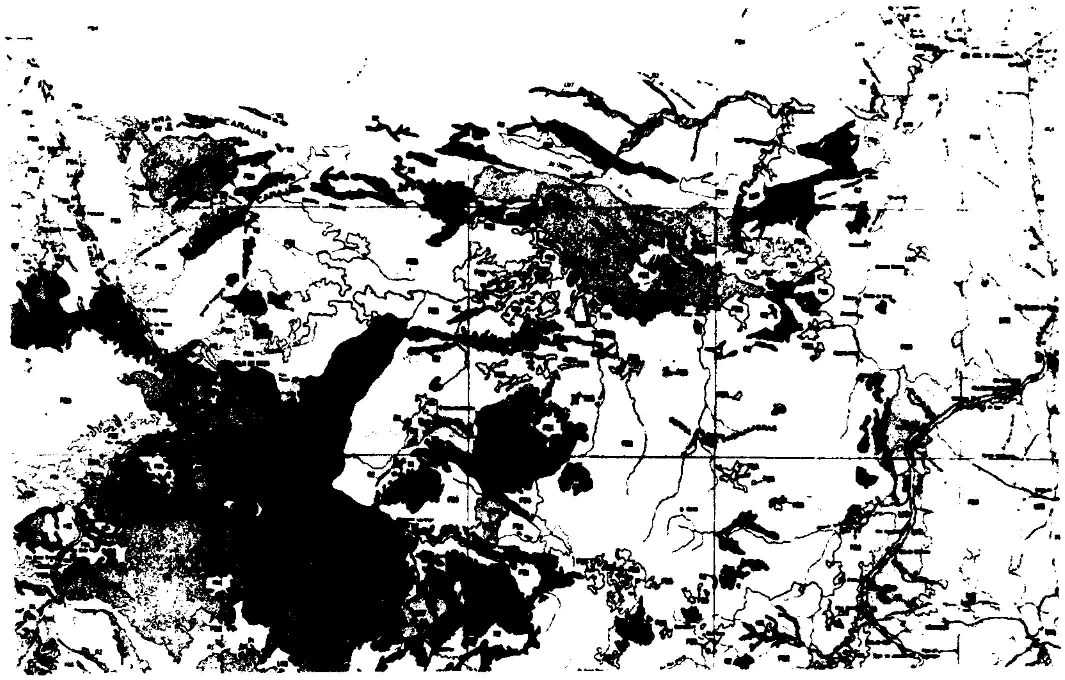


Figure 9 – Project RADAM Soils Survey Map

To supplement standard black and white radar imagery, there is available a series of special image products which enhance the use of the original radar data. These products are generally available only from coherent radar systems that provide the capability of multiple reprocessings of the original data film.

One of these processing products is a two-color radar image (usually red and yellow) in which the larger radar returns are automatically separated from their background by color. This tool is particularly useful in the evaluation of forest areas because it provides an additional means of identifying large trees. It also is useful in the survey of remote areas for man-made or cultural objects.

A second special product of the radar system is composite imagery formed by the photographic addition of radar and Landsat imagery. Because the geometries of the two systems are accurate, it is possible to make composites of small areas without geometric correction Figure 10 illustrates the successive exposures required to generate a composite. In the figure, W represents a white light source; F_4, F_5, and F_7 are the blue, green and red filters normally used when compositing Landsat data; L_4, L_5, and L_7 represent the Landsat scenes; and R is the radar image. Variation in the composite can be obtained by varying the relative exposure of each scene, by varying the relative density of the radar image in each scene, and/or by adding exposures of either radar or Landsat alone. Figure 11 is a black and white rendition of a composite of an area around San Diego, California. The lower left portion of the image shows the Landsat composite by itself. The upper right half of the image shows the detail that radar can add to the composite. Of particular interest is the clearer definition of field patterns, cultural objects, and the less distinguishable terrain features. The pronounced horizontal line is the Mexico-USA border.

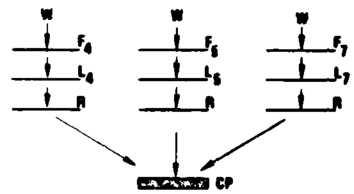


Figure 10 – Composite Image Production Method

Other interpretation aids can be generated from the original synthetic-aperture data film. These include multiple correlations for added color enhancement, systematic scale error corrections for block adjustments or composite image matching, and coherent optical filtering.

5. MULTIPLE IMAGE TECHNIQUES

The discussions thus far have dealt with the application of a single frequency, single polarization radar which has generated a single image of the terrain in question. The generation of multiple radar images can in many cases provide additional data concerning the terrain in question. The goal of such multiple image programs is to obviate the need for any ground reconnaissance and to establish classifications of terrain types or crops or moisture content by reference to previous surveys or keys.

The methods employed to provide differentiation of images are at least three in number and are:

1. Polarization diversification
2. Frequency diversification
3. Depression angle diversification.

Figure 11 shows two images of the same area made simultaneously with an x-band synthetic aperture system. Transmission was vertically polarized, and the received images are vertical on the left and horizontal on the right. Several differences are apparent in the imagery:

a. variations in field patterns
b. improved definition of large targets in the horizontal-vertical image
c. differences of sea return.

Similar effects can be achieved using images found at different wavelengths; and the two techniques can and have been combined to provide multiple images. The principal disadvantage of the approach is the hardware complexities engendered by diverse RF requirements and the multiple channel recording of data.

The use of depression angle variations has also been employed to generate separate images for separate analysis but is more often employed to create stereo pairs. Figure 12 shows a stereo pair created by radar. This imagery has also been used to create a pair of composites of radar and Landsat (not shown). Bands 4, 5, and 7 were combined in false color and the radar added as previously discussed. The radar not only adds the stereo effect but also enhances the detail by virtue of its higher resolution (about eight times that of the Landsat).

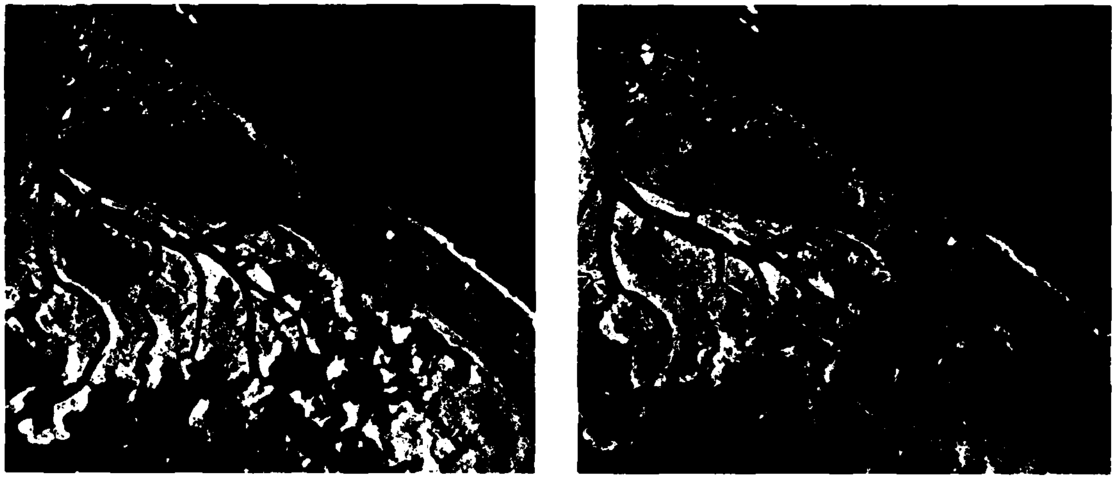


Figure 11 — Composite of Landsat and Radar — San Diego, California

Vertical Transmit — Vertical Receive *Vertical Transmit — Horizontal Receive*

NASA RADAR

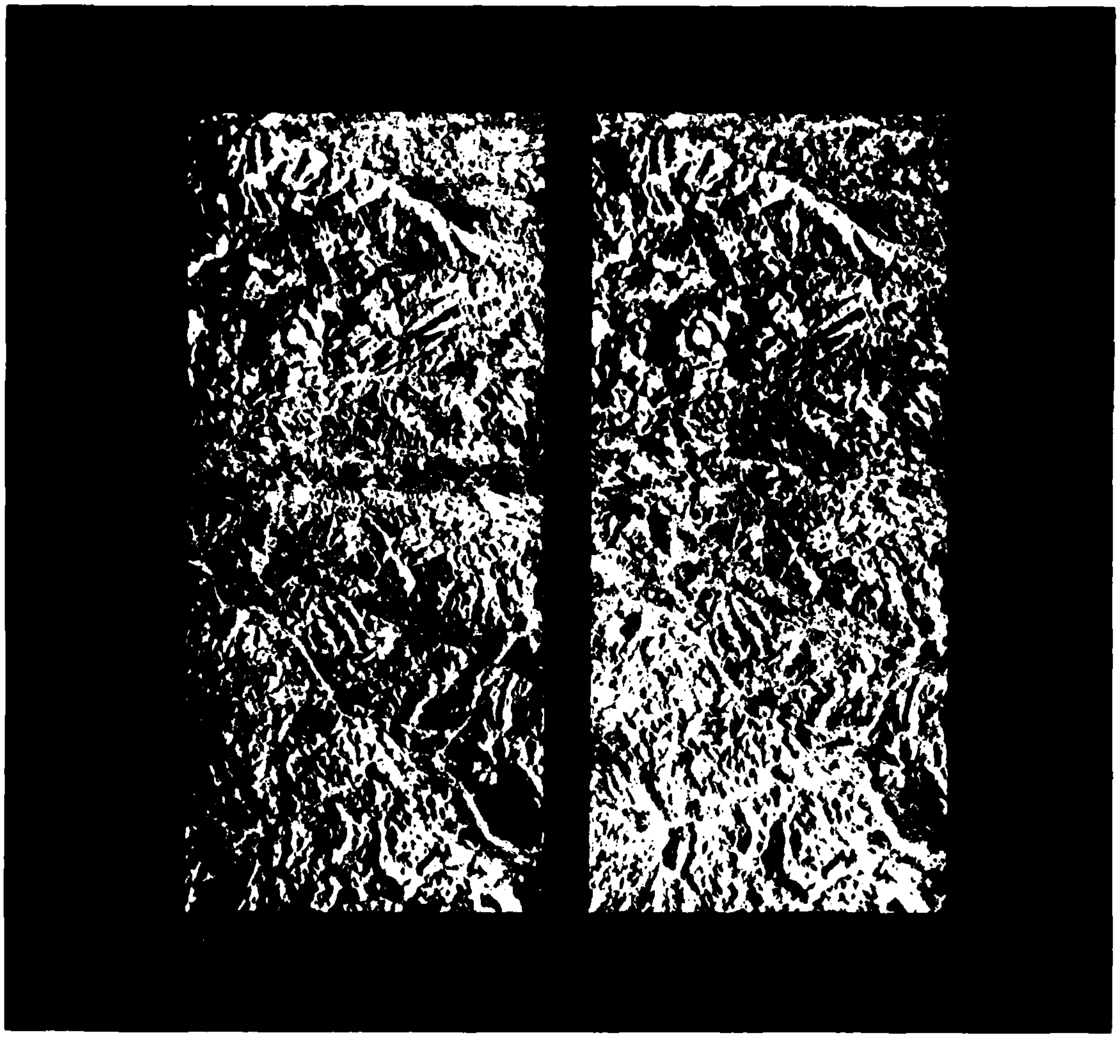


Figure 12 – Stereoscopic Radar
Australia Scale 1:200,000

6. APPLICATIONS OF RADAR

Radar as a remote sensor can be applied to several different disciplines, such as cartography, geology, forestry, agricultural analysis, drainage studies, flood evaluation, and others. All these uses are applicable to land use studies because land use decisions must take into account *the totality* of data regarding the earth's surface and its substructure.

In the realm of mapping, radar has been used as the definitive tool in many areas of South America and the Far East. In these locations, no other method would suffice because of constant cloud cover and inaccessibility by land. In addition, radar can be used to update and correct existing quad maps of areas previously surveyed.

Perhaps the most striking applications of radar occur in the areas of geological survey. The ability of radar to emphasize the surface evidence of underground geological phenomena has proved itself of great value. Figure 13 shows an area in the upper Amazon where this application is well documented. This figure contains a portion of a quadrangle map made entirely from radar data, together with an overlaying geological interpretation. The two points marked are existing, producing oil wells (now capped). They are located with a particular relation to an anticline structure as indicated by the symbol .

The geological interpretation shows several other similar structures in the region which are not explored and were not previously identified. The ability to locate these structures accurately will enable exploration teams, such as seismic surveys, to restrict their efforts to the potentially productive regions. The savings *in time and money may exceed the survey costs* manyfold.

Figure 14 is a portion of a similar adjacent area. Attention is called to the valley in the lower left portion of the figure. This valley is a definite prospect for the location of a hydroelectric plant. The two light areas identify alluvial deposits of sand and gravel, an important resource if extensive construction is to be carried on in the vicinity.

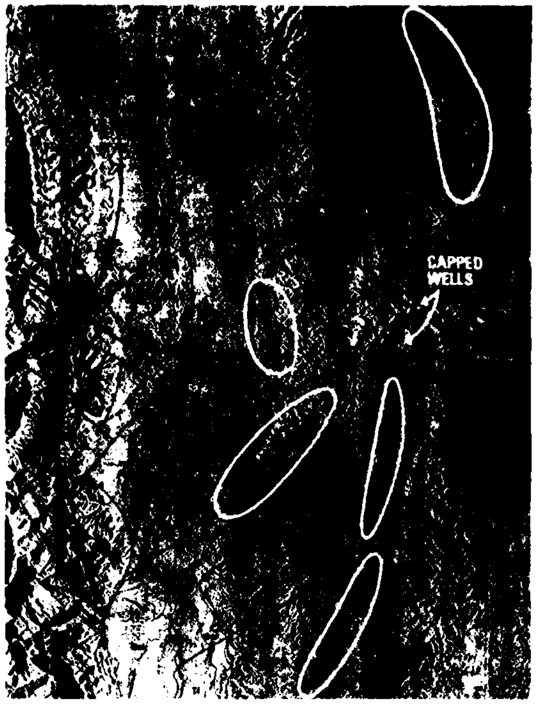


Figure 13 – Geologic Interpretation of Part of the Upper Amazon Basin (Peru)

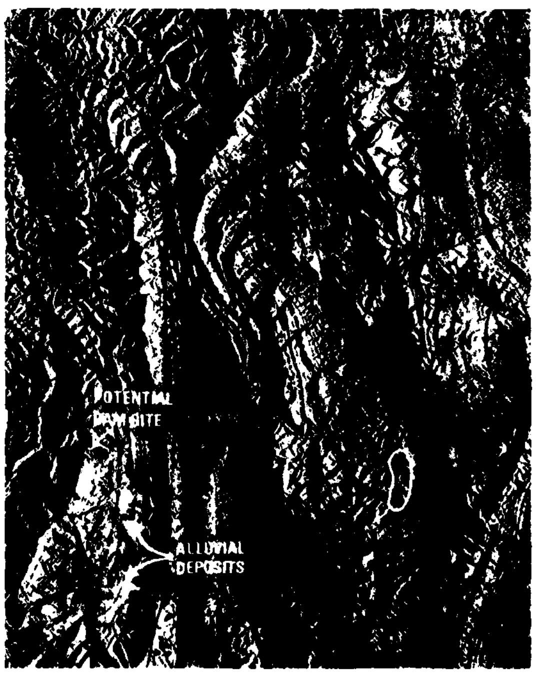


Figure 14 – Radar Image Showing Alluvial Deposits (Peru)

Mention of the application of radar to forestry surveys has already been made. Figure 15 shows an area in northern Arizona in the United States. The area is covered with Douglas fir and other coniferous trees. In several instances, measurement of the size of individual trees can be obtained from their shadows. The size data thus obtained can yield information to correlate with the color processed data referred to previously. Specifically, the area shown in the white circle provides measurable shadow length which permits the height of the group of trees to be estimated as 20 to 25 meters. It is not possible, however, to say how many large trees are in the group from the black and white image. Color processing, however, shows that the group in question has four large trees as evidenced by the four yellow targets on a red background. Other smaller trees may also exist. Once an approximate value for the tree size corresponding to the yellow returns is obtained, a statistical count of all trees over a certain size is possible. Alternatively, the color level can be determined by a sample field survey of an accessible area.

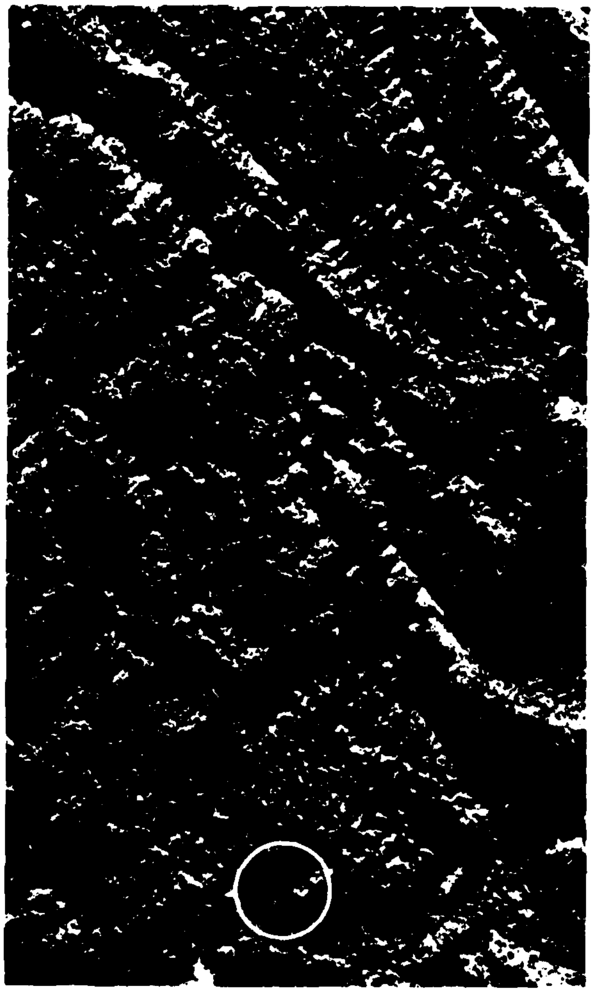


Figure 15 – Northern Arizona Enlargement Showing Tree Shadows

Figure 16 is an example of a radar image in which sensitivity to drainage patterns is evident. The figure is another area of the Amazon jungle. Here it is possible to trace drainage patterns and identify ancient river courses. In many cases, these observations cannot be made visually nor with cameras. Two problems account for this fact: first, the extensive cloud cover, and second, the almost uniform appearance of the jungle to the human eye as well as to the camera.

Figure 16 – Drainage Patterns – Upper Amazon

Finally, mention should be made of the use of radar in soil surveys and other direct land use applications. Radar cannot, of itself, provide direct data regarding soil types. However, the sensor has been extensively used to define the boundaries of soil domains utilizing radar evidence of changes in terrain slope, vegetation, and drainage. Once these domains are defined, a relatively small number of field samples has sufficed to provide a comprehensive soil survey chart. The case cited in Figure 14 and the Brazil Soil Survey Map of Figure 9 are examples.

Figure 17 – Synthetic Aperture Radar Coverage of South America

7. COMMERCIAL RADAR SYSTEMS

Large areas of the world including more than half of South America have been covered by radar surveys (figure 17). The leading commercial system in terms of area coverage is a synthetic aperture radar built by Goodyear Aerospace Corporation in Litchfield Park, Arizona and operated in partnership with Aeroservice Corporation of Houston, Texas. The MARS Company of Phoenix, Arizona also offers a survey service using a Motorola-built real aperture radar and there is now a Canadian Company providing a synthetic aperture capability.

In addition to these commercial operations, NSA is operating an experimental coherent aperture radar which has performed surveys for USGS and DMA among others.

next page is 41

THE GOES DATA COLLECTION SYSTEM

Dr. Clifford A. Spohn

National Environmental Satellite Service
National Oceanic and Atmospheric Administration
Washington, D.C. 20233

ABSTRACT

The GOES Data Collection System has been in full operation since 1975. Significant improvements in the system were made in 1977 and a second upgrade is planned for 1980. Presently the system can accommodate self-timed, interrogated, and alert platforms; after upgrade it will also accommodate random access platforms. The GOES system provides for the collection of environmental data, for NOAA and other U.S. and foreign agencies, where commercial communications are nonexistent or inadequate.

In 1974, after the launch of NASA's Synchronous Meteorological Satellite (SMS-1), the prototype of our present GOES satellites, NOAA began the operation of a system designed to provide the capability for the rapid collection of environmental data from remote locations or locations which did not possess adequate communications to get such highly perishable data to users in adequate time. That system was the GOES Data Collection System, or DCS. Since the system had no platform location capability, it was limited to collecting data from fixed platforms or from platforms which could include their location in their messages, such as ships or aircraft.

For the first several years the system was operated on a trial basis. During this time NOAA worked with the user group to plan for a more automated ground system which would be able to provide a more dependable level of service and reliability for our users. The Phase II, largely automated system was designed, procured, and installed so that it went into operation in 1977. Significant increase in reliability and a large growth in use of the system resulted.

During the next several years it became apparent to both NOAA and user agencies that more platform monitoring information was required to increase system reliability. We are right now in the process of evaluating responses from industry to an RFP for the design and manufacture of an automated monitoring system which will provide the kind of platform performance information required for proper monitoring of the overall system performance.

At the present time the system is designed to support the collection of data from three types of platforms. The first, and simplest, of these is the self-timed platform. Such a platform consists of a radio transmitter, a clock, and the sensor or sensors providing the input data. The platform is assigned a reporting frequency, an identification number, and a reporting time or slot. Most self-timed platforms report every three or six hours, although hourly reporting intervals have been permitted when the value of the data warranted such use. For self-timed platforms a reporting interval of a minute is the basic unit. Since most platforms require only about 20 seconds to transmit their message, this provides a "cushion" of 20 seconds on either side of the reporting interval to allow for some clock drift during the time (which may be up to a year) when the platform is unattended. Because of its simplicity, the self-timed platform is the least expensive type. It has also proved to be the most reliable, generally achieving reliability levels at or above 95 percent. Most of the platforms currently in the system are self-timed platforms.

The second type of platform used in the GOES DCS is the interrogated platform. In this case the data collection platform (DCP) consists of both a radio receiver and a radio transmitter, plus the sensor complement. The platform is assigned a frequency and an identification number or address, but no reporting time. Data are collected by transmitting, on a separate interrogation frequency, the address of the platform. Interrogation platforms monitor all transmission on the interrogation frequency. Whenever a platform receives its own address, it activates its transmitter and sends its data message on its assigned reporting frequency. If a platform fails to respond to interrogation it is immediately reinterrogated. These interrogations are repeated until a response is received, or until a previously agreed number of reinterrogations have been tried. Although interrogated platforms are initially set up with a standard reporting interval in the interrogation schedule (i.e., every three or six hours), the interval can be changed whenever the user desires to interrogate the platform more frequently, as would be the case if a critical situation was expected or was present. To change the interrogation schedule, the user need only notify the duty operator at DCS Central in the World Weather Building in Camp Springs, Maryland. Interrogation DCP's are more expensive than self-timed (usually several thousand dollars) and less reliable. Reliability levels for interrogated platforms have generally been in the 85-90 percent level. However, their much greater flexibility makes them much more useful for certain applications.

The third type of platform in the present DCS is the alert platform. The alert platform is a special type of interrogated platform which has the capability to transmit on more than one frequency. One or more sensors on the platform are equipped to recognize the onset of a critical condition, for instance, the rapid rise of a stream level or the beginning of exceptionally heavy rainfall. When the pre-established threshold is exceeded, the sensor will trigger the radio set to transmit on its secondary, or alert, frequency. In this transmission all that is sent is the platform address. Whenever a platform address is received by the GOES ground station, the computer immediately puts that station at the head of the interrogation queue and collects its data by a normal interrogation. At the present there are relatively few alert platforms in the system. As might be expected, alert platforms are the most expensive platform type in the system.

An additional capability available with interrogated platforms is the capability to command the platforms to alter their mode of operation. Under the identification designator scheme used, there is an order of magnitude more addresses possible than the number of platforms the system could handle. The scheme being utilized is then to use the excess addresses as platform commands. A platform to be commanded would then be assigned a series of addresses. One of these addresses would cause the platform to report, but the others would cause the platform to execute other functions, such as turning sensors on or off, resetting a clock to alter the reporting interval, etc. (In this latter case, although we are discussing interrogated platforms, a combined interrogated-self-timed platform is addressed. Here the greater reliability of the self-timed system is obtained by having reporting under clock control, the interrogation feature being used only to change the reporting interval as desired by resetting the clock function.)

With the addition of the automatic monitoring system (AMS) to our ground equipment, hopefully during 1980, we anticipate being able to accept a fourth type of platform into the system, namely, a random access platform. Under our present system of monitoring, all normal messages are "expected messages." That is, the system knows when self-timed platforms are scheduled to report and it knows which platforms it has interrogated and should be receiving a report from. Any data report received from a platform which was neither interrogated nor scheduled to report is treated as an "unexpected message" and not handled as normal traffic. It poses a particular problem if the platform address, which heads platform transmissions, is garbled. We would then have no way of identifying the platform.

When random access platforms are accepted into the system, certain reporting frequencies or channels will be established for random access reporting only. All messages on these channels will be "unexpected," or the unexpected will be expected. With the AMS altered to handle random access messages, we will still be able to provide a minimum monitoring capability for such platforms.

Why the desire for random access (RA) reporting? RA will significantly increase system capacity, while it is expected to provide reliability equivalent to the self-timed system. A channel being used for self-timed platforms can accommodate 180 such platforms if they are reporting every three hours and each is assigned a one-minute reporting interval. The same channel using random access is projected to accommodate more than

200 platforms an hour. RA platforms are anticipated to cost less than self-timed platforms, because a high quality, very stable clock is not required. Finally, RA platforms can be built so that the timing between reports is controlled by the phenomena being observed. As an example, a river level gauge could be set so that when the river level is at or below normal it will only report once a day. As the river level rises above normal it will begin to send reports every six hours. When the river approaches flood stage, reports will be sent every hour and, finally, at the most critical point, 15-minute reporting will be instituted. These changes in reporting interval, keyed outside the system, will cause no system problem since all of the messages, at any interval, were unexpected and were handled identically.

Message dissemination for all types of platforms is handled identically. The data addresses are checked and the messages stored in designated areas or bins of a computer disk, available to the user at his call-up. For those users who require their data immediately, dedicated communication lines can be arranged (at the user's expense) and the data will be both stored and transmitted at once. Otherwise the user can call on his "bin" via a computer-to-terminal dial-in service and receive his data as desired. Data are held in the bins a minimum of 24 hours, to permit requests for reruns if an initial transmission were garbled. Data can also be directed to up to three other bins, where users wish to have cooperative arrangements for exchanging data. Finally, any user wishing to may receive his data directly from the satellite via his own direct readout station, using the GOES DCS Central as a backup.

The GOES DCS was set up initially to meet the needs of NOAA. Since there are a number of other federal agencies whose data needs matched closely those of NOAA, especially in hydrology, these agencies were also invited to make use of the system. Finally, use of the system was extended to any agency whose data would be useful to a NOAA unit or would support a program which NOAA was also supporting. We are now proposing to extend use of the system to any agency, domestic or foreign, whose use of the DCS will further a program of the U.S. Government and also to users whose data are required by a state or local government. We expect this new policy to be published this year.

In order to enter the system, the user must be collecting environmental data (defined as parameters of the physical environment), must agree that NOAA and other U.S. Government agencies may have free access to the data, must use a radio set whose characteristics meet our established technical specifications, must be responsible for all costs of the platform and of the relay of the data from NOAA to their facility, and must not have access to adequate commercial communications at the locations proposed for the platforms.

NOAA expects to continue the present geostationary DCS for the indefinite future, subject to the availability of future appropriations.

In the event of any major changes in or termination of the DCS we would expect to be able to provide three to five years' advance notice to our users to permit them to have time to arrange for alternate means of data collection.

ENERGY LOSS SURVEYS USING THERMAL IR TECHNOLOGY

Lewis E. Link, Jr., Ph.D

U. S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

ABSTRACT

Airborne thermal infrared (IR) sensor systems can provide a rapid and cheap means to survey entire installations for energy loss phenomena; i.e., leaks in buried heat distribution lines, roofs with inefficient insulation, and roofs with entrapped moisture. Application of thermal IR to facilities surveys requires careful consideration of weather conditions and the time-of-flight. Guidance for mission planning, typical results obtainable and sources of assistance for operational surveys are provided.

1. INTRODUCTION

Energy conservation has become an important consideration in facilities management at government installations. Implementing effective energy conservation measures is at times complicated by the large areal extent and diversity of facilities on many installations. One problem is identifying sources of excessive energy consumption so that corrective measures can be initiated. Recent studies at the U. S. Army Engineer Waterways Experiment Station (WES) have shown that thermal infrared imaging systems available in both military and commercial reconnaissance aircraft can provide valuable information about individual structures and utilities that have excessive energy losses. Imagery of a number of Army, Air Force, and civilian government installations obtained with various military and commercial aircraft/sensor systems revealed leaks in buried steam and condensate pipelines, roofs with inadequate or water-saturated insulation, and differences in internal heating levels of housing. The following paragraphs give a brief outline of the basic phenomena detected, how IR sensor systems work, mission planning for applying IR sensors to facilities surveys, results obtainable, and sources of assistance for operational use of these techniques.

2. PHENOMENA DETECTED

Most energy loss phenomena have an associated increase in temperature of some physical feature. For example, the presence of moisture in the insulation of a built-up roof can drastically alter the thermal properties of the roof. Thus, when dry and wet roofs are subjected to energy sources (i.e., the sun and the internal heat of the building) they can potentially have different temperatures. Figure 1 illustrates this phenomenon, as well as the fact that the roof temperatures and the difference in temperature between wet and dry roof areas vary with the time of day. A leaking steam line will cause the soil above the line to have a higher moisture content and also provides a significant energy source, both of which can cause the area above the leak to have a temperature (at certain times of day) higher than that of the surrounding soil. Similarly, heated buildings will lose more energy through a poorly insulated roof having a higher

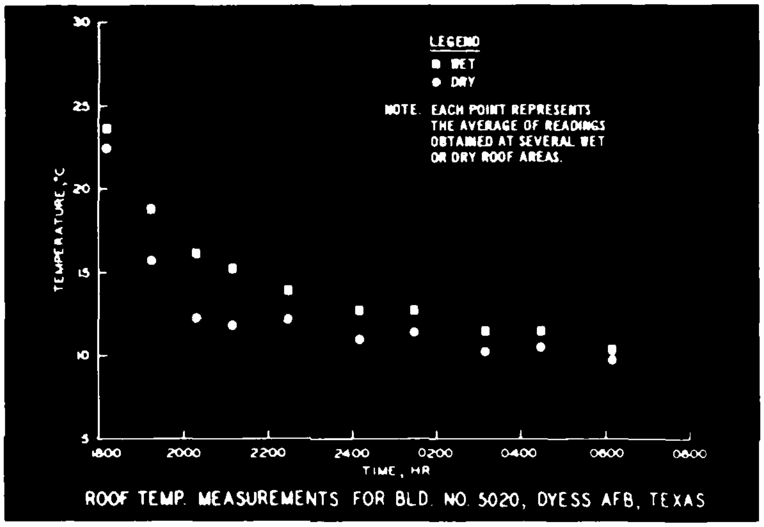


Figure 1. Roof temperature data

temperature and radiating more energy; also, a faulty steam trap, bus-bar, or transformer will be considerably higher in temperature than one operating properly. This all boils down to one phenomenon: change in temperature and the associated differences in the amount of energy radiated by the items which have different temperatures. This is the key to the ability to detect such problems.

3. THERMAL IR SENSOR SYSTEMS

The sensor systems that allow detection of energy loss phenomena are thermal IR scanner systems. These sensors differ from aerial photographic systems in that they respond to energy radiated by terrain features (as opposed to energy reflected). Any feature with a temperature above absolute zero (0 K) radiates energy; the higher the temperature of the feature, the greater is the amount of energy radiated. As such, the sensors can detect differences in the temperature of features. The amount of energy radiated is quite small and very special cryogenically cooled detectors are needed to measure it; semiconductor crystals such as mercury doped germanium are normally used. Figure 2 shows a schema of a typical airborne thermal IR scanner system. As the mirror rotates, the detector receives energy from a path on the terrain perpendicular to the flight of the aircraft. Recording the detector output for successive scan lines

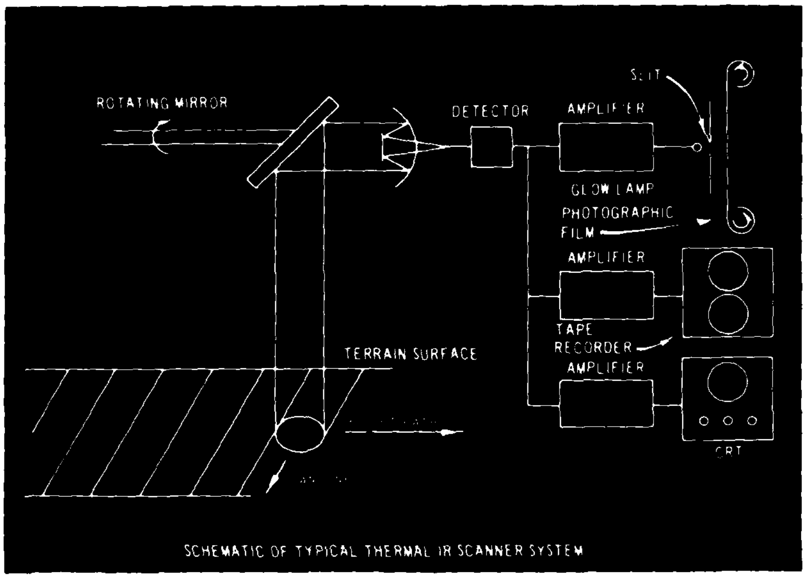


Figure 2. Schema of typical thermal IR scanner system

creates an image of the terrain. Smaller, more compact devices that can be hand-held are also available and operate on similar principles. Their output is normally displayed on an image on a cathode ray tube or, for nonimaging devices, a simple digital readout of the apparent temperature of an item being surveyed. (Apparent temperature is the temperature an IR sensor perceives an item to be based on the amount of energy it radiates. Since most items are not perfect radiators, it is usually less than the actual temperature.)

4. APPLICATION OF AIRBORNE THERMAL IR SENSOR SYSTEMS AND MISSION PLANNING

Airborne thermal IR sensor systems are best applied as reconnaissance tools to rapidly survey facilities over large areas of terrain, such as an entire town, industrial-commercial complex, or military installation. Their greatest single advantage is the ability to acquire for a large area a photo-like image that can be quickly interpreted. Successful application of airborne thermal IR devices requires execution of the following steps: assemble available data on facilities; plan thermal IR imagery mission;

acquire imagery; and interpret imagery. Of these, mission planning deserves particular attention.

The total heat balance of a feature defines its temperature at any given time. Because the heat balance changes with daily and seasonal variations in energy sources and weather conditions, the temperature of a feature is quite dynamic. The idea is to acquire thermal IR imagery when excessive energy loss causes the most impact on the temperature of a building exterior or terrain surface above a heat distribution line. This is common when the influence of other major heat sources (e.g., the sun) are at a minimum.

Imagery should be collected on a cold, clear night when buildings and the surrounding terrain are free of snow and standing water. To maximize the information obtained, building thermostats should not be lowered on the day of the mission. The best time of day for detecting areas of entrapped moisture in built-up roofs is between 2130 and 2300 hours. The best time of day for detecing leaks in buried steam/condensate lines or differences in the insulation efficiency of roofs is between 2300 and 0200 hours. A single mission to cover all aspects is best flown between 2200 and 0100 hours. The aircraft should fly as low as possible (500 to 1000 ft above the ground) and flight lines should be spaced so that a 35 to 50 percent overlap occurs for adjacent flight lines.

5. RESULTS OBTAINABLE

Studies to date have shown that three types of energy loss phenomena were readily detected on the thermal IR imagery. These types were (a) leaks in underground heat distribution pipes, (b) insufficient roof insulation, and (c) insulation with entrapped moisture.

Figure 3 is an example of the appearance of a leak in a buried condensate pipeline. This image was obtained at approximately 2400 hours on a March night. The image in Figure 4 illustrates the appearance of roofs with different insulation efficiencies. Because more energy is escaping through the roof with less effective insulation, it appears lighter (warmer) on the thermal IR image than the roof with more efficient insulation. Figure 5 illustrates the appearance of roof areas with entrapped moisture. The areas with entrapped moisture always appear as lighter tones on the nighttime imagery because of both stored solar energy and increased heat loss due to the reduced efficiency of the wet insulation.

In a recent study conducted at the Los Alamos Scientific Laboratories, a total of 14 potential pipe leaks were identified on the imagery. Subsequent ground checks showed that 13 were in fact leaks. Virtually all roof areas identified on the imagery as having energy loss problems due to entrapped moisture or insufficient insulation were verified by subsequent on-the-roof checks. A few potential problem areas were found to be due to puddles of water on the roof surface. Another study at Robbins Air Force

Figure 3. Thermal IR image showing leak in buried condensate pipe

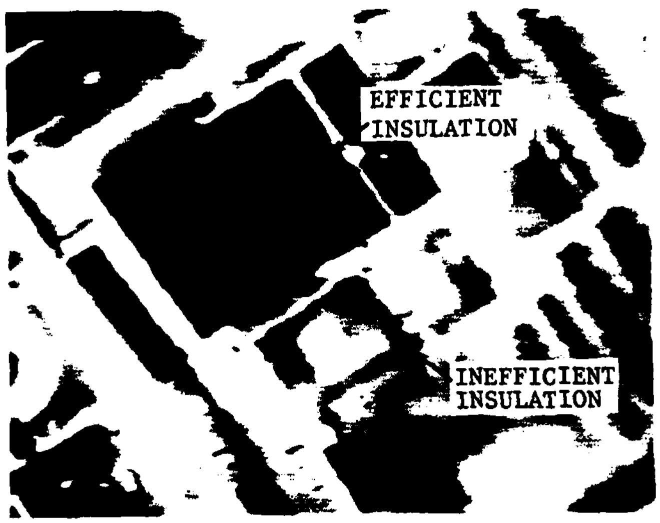


Figure 4. Thermal IR image showing roofs with different insulation efficiencies

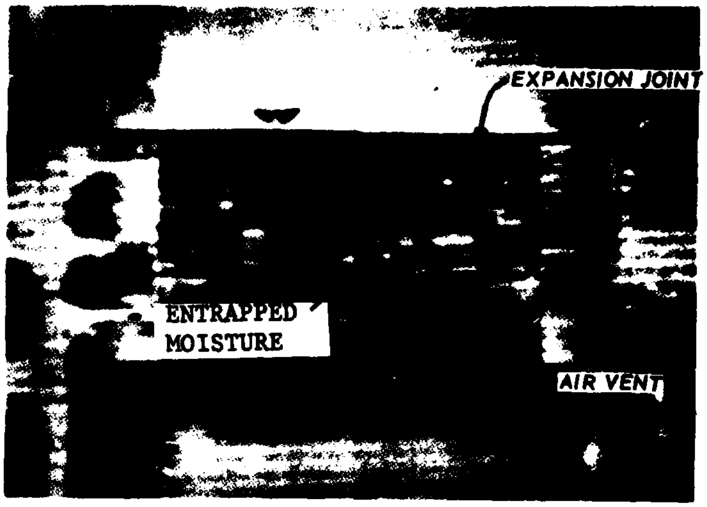


Figure 5. Thermal IR image showing roof areas with entrapped moisture

Base had similar success and demonstrated for the first time the excellent results obtainable from the new thermal IR scanner systems being placed in the Air Force Tactical Reconnaissance RF-4C aircraft. In all cases, it is imperative to follow the reconnaissance survey with ground-validation of the results. This can be accomplished with such devices as nuclear moisture meters, hand-held IR sensors, or at time by simple visual or manual sampling procedures. Hand-held IR and nuclear meter devices are also valuable for surveying individual roofs for entrapped moisture. The reconnaissance survey from an aircraft is only cost effective if a large number of buildings need to be surveyed.

6. SOURCES OF ASSISTANCE

Research within the Army to develop the airborne reconnaissance thermal IR survey techniques has been centered at the WES, while concurrent work on the use of hand-held IR devices has been done at the Cold Regions Research and Engineering Laboratory (CRREL). The Construction Engineering Research Laboratory (CERL) is responsible for overall management of the Corps energy and roof research efforts. The technology for conduct of nuclear meter roof surveys was developed at the WES. Within the Army, the responsibility for operationally conducting facilities energy surveys resides at the Facilities Engineer Support Agency (FESA), Ft. Belvoir, Virginia. The FESA personnel have interacted with WES and CRREL researchers to become familiar with these new techniques and can provide services on a request basis.

Several documents are available for guidance. These include the following:

a. Recommendations for Implementing Roof Moisture Surveys in the U. S. Army, CRREL Special Report 78-1, August 1978, (For Official Use Only).

b. Guide for Airborne Infrared Roof Moisture Surveys, WES Instructional Report M-78-1, January 1978.

c. Guide for Nuclear Meter Roof Moisture Surveys, In preparation at WES.

d. Information Paper on Infrared Utilization for Facilities Engineers, FESA-RT 2021, U. S. Army Facilities Engineering Support Agency, Ft. Belvoir, Va., August 1976.

e. Applications of Thermography for Energy Conservation in Industry, NBS Technical Note 923, U. S. Department of Commerce, National Bureau of Standards, Washington, D.C., October 1976.

In addition, commercial services are available for both IR and nuclear meter surveys. A partial list of companies that can acquire thermal IR imagery is given in Table I. A listing of companies that provide nuclear meter equipment or survey services is given in Table II. These lists are expanding constantly and the services becoming more and more available. In this age of inflation and higher energy costs, the use of IR facilities survey techniques can substantially reduce both the man-hours and ultimate cost of maintenance and repair of facilities. Advantages of knowing the full extent of the job will permit more exact cost estimating and in turn more tightly written contracts, avoiding the problems inherent in the "repair as necessary" type contracts.

Table I. Aerial Survey Companies Confirmed to Offer Thermal IR Survey Capabilities

Mark Hurd Aerial Survey
Goleta, California
805-967-1261

V.T.N.
2301 Campus Drive
Irvine, California 92664
714-833-2450

Esch Tech (North American Rockwell)
2330 Cherry Industrial Circle
Long Beach, California
213-630-4642

Western Aerial Photos, Inc.
303 Convention Way, Suite 2
Redwood City, California 94061

Cartwright Aerial Surveys, Inc.
Executive Airport
Sacramento, California
916-422-6424

Murray-McCormack Aerial Surveys
Sacramento, California
916-391-1651

MapCotec, Inc.
P. O. Box 5267
Daytona Beach, Florida 32020

Chicago Aerial Survey
2140 Wolf Road
Des Plaine, Illinois 60018
312-298-1480

Aerial Service, Inc.
Cedar Falls, Iowa
319-266-6181

Photo Science, Inc.
7840 Airpark Road
Gaithersburg, Maryland 20760

Daedalus Enterprises, Inc.
P. O. Box 1869
Ann Arbor, Michigan 48106
313-769-5649

Abrams Aerial Survey Corporation
123 N. Larch Street
Lansing, Michigan 48903
517-372-8100

Lockwood-Kessler-Bartlett
One Aerial Way
Syosset, L.I., New York 11791
516-938-0600

Hunting Survey and Consultants,, Ltd.
10 Rockefeller Plaza
Suite 705
New York, New York 10020

Kucera & Associates, Inc.
700 Reynolds Road
Mentor, Ohio 44066
216-255-4700

Air Survey Corporation
Newton Square South
Reston, Virginia
703-471-4510

Legislative Council of Photo-
grammetry (2)
1001 Connecticut Ave., N.W.
Suite 800
Washington, D. C. 20036

TREMCO, Inc.
10701 Shaker Blvd.
Cleveland, Ohio 44104
216-229-3000

Table II. Nuclear Meter Equipment Manufacturers*

Campbell Pacific Nuclear Corp. 130 South Buchanan Circle Pacheco, California 94553 415-687-6472	Troxler Electronic Laboratories, Inc. P. O. Box 12057 Cornwallis Road Research Triangle Park, N.C. 27709 919-549-8661
Nuclear Instruments Corp. 2300 W. Camden Road Milwaukee, Wisconsin 53209	The Seaman Nuclear Corp. 3846 West Wisconsin Avenue Milwaukee Wisconsin 53208 414-342-1030

Nuclear Meter Survey Services*

Rupo Technical Services, Inc. Roof Maintenance Systems 8018 So. 27th Street Oak Creek, Wisconsin 53154 414-761-0270	Monroe Company, Inc. 30801 Carter Street Cleveland Ohio 44139 216-248-7890
Gammie Nuclear Service Co. 3737 Mt. Prospect Road Franklin Park, Illinois 60131 312-766-8770	

* List limited to available information.

HYDROLOGIC INFORMATION TRANSFER SYSTEM
"TWX POLLING SYSTEM"

George N. Lathrop, Hydraulic Engineer
Reservoir Control Center, MRD, Corps of Engineers

1. DESCRIPTION. This system collects daily hydrologic meteorological and power data from the six main stem reservoirs on the Missouri River. The data is obtained by computer controlled, paper tape driven, teletype machines at each dam beginning at downstream end of system. Copies are printed in the Omaha District and the MRD Reservoir Control Center. Extracts of the data are stored in the Missouri River Automated Data System (MRADS) on the Boeing Computer Services computers. River stages and corresponding discharges are obtained from the Weather Service's AHOS data base in Medford, Oregon and MRADS with the results being stored in MRADS. Daily Missouri River Bulletins and forecasts are prepared from all this data.

Since the HITS system begins data collection and processing at 0430 hours central time the final results, bulletins and forecasts can be finished by 1030 hours ready for use in daily briefings and decision making. Normally, the longest part of the HITS data collection and processing are finished when the Reservoir Control Center opens at 0630.

If processing is interrupted operator correction is facilitated by interactive indications of problems, machine printed instructions for corrections and question and answer input of corrected data.

2. ADVANTAGES. The system replaces manual methods and has the following advantages:

a. More timely and accurate final reports.

b. Automatic data supply for larger computer systems which avoids manual insertion.

c. Low level of skill required by power plant control room operators who prepare the source data at night and on weekends. A non-rigid format is used with master paper tape for the input data.

d. Most of the data is collected and processed before the Reservoir Control Center office opens at 0630 leaving plenty of time for any necessary error corrections.

e. Machine produced error indications are produced with printed instructions for interactive correction:

(1) Possible causes.

(2) Off-line correction procedures.

(3) On-line correction procedure with questions and answers.

3. DESCRIPTION OF DATA AND RESULTS.

a. A summary of the data is listed below:

(1) Hourly.

(a) Generation
(b) Turbine discharge
(c) Spilled discharge
(d) Pool level

(2) Thrice Daily.

(a) Tailwater elevation
(b) Yankton stage
(c) Wind and air temperatures

(3) Once Daily.

(a) Spencer discharge
(b) Maximum and minimum temperatures
(c) Precipitation
(d) Evaporation data
(e) Miscellaneous data for tributary reservoirs
(f) Penstock water temperatures

b. From this the following results are derived:

(1) A Power Table showing:

(a) Hourly generation for each plant and system. High and low values are shown.

(b) Total daily and average generation for each dam and system.

(c) Plant and system load factors.

(d) Relative efficiency for each plant expressed as KWH per cfs where the KWH are for the whole day and the cfs is the average discharge for the day.

(2) A hydrologic data table showing:

(a) Hourly average discharges thru the power plant with high and low values being shown.

(b) Average hourly discharges thru outlet works and/or the spillway.

(c) Daily totals of released water volume in day second feet and average daily discharges.

(d) Pool elevations and tailwater elevations for 0700, 1500, and 2400 hours for each dam.

(e) Intake water temperatures.

(f) Yankton stages for 0700, 1500 and 2400 hours.

(g) Spencer daily average discharge.

(3) Meteorological data and tributary reservoir data are collected for information and manual use.

c. Data for a daily plot of power operations is prepared. Optional plotting is done by computer.

d. The following value for each dam are automatically sent to the MRADS data base for each dam.

(1) Total generation.
(2) Average discharge.
(3) Pool elevations.
(4) Tailwater levels.
(5) Water temperatures.

The system total of generation is also sent to the data base.

e. Data for the monthly summary of power operations is updated daily using data from results of (1) and (2) above.

4. EQUIPMENT.

a. Model 33 Teletype machines with paper tape punches and readers are used to send the data from the dams to the Reservoir Control Center. These are also used for normal teletype communications between offices and projects.

b. A Hewlett Packard programmable desk top calculator is used to receive, process and store the data. Principal components are:

(1) HP 9830 calculator with internal cassette.

(2) HP 9866B Thermal Printer.

(3) HP 9862B Plotter.

(4) Infotek Systems FD 30-A floppy discs, master and slave.

(5) Infotek RT-30 Interrupt Clock.

(6) Data phone 103 J with automatic calling unit and modem.

(7) Modem for teletype interface.

c. Hewlett Packard Read Only Memory (ROM) Modules:

(1) String variables.
(2) Matrix arithmetic.
(3) Plotter control.
(4) Data Communications I and II.
(5) Extended input/output.
(6) Advanced Programming I and II.

d. Infotek ROM's:

(1) Fast Basic I, II and III.

e. Miscellaneous:

(1) An electric clock to initiate operations before normal working hours.

(2) A special clock which interrupts programs so unanswered telephones and unresponsive teletypes can be retried (Infotek RT-30).

5. The following programs are used with each after the first being called by its predecessor. The first is called by an electric time clock at 0430 hours.

a. TELETYPE POLLING PROGRAM polls the teletype at each power project and starts its paper tape. The data is printed in the Reservoir Control Center and the Omaha District on teletypes. It is also stored on a floppy disc in the desk top computer.

b. DATA DISTRIBUTING PROGRAM takes the data from the disc for each project and distributes it among four matrices for future use. These are stored on the disc. Data that is sent by projects for information only is discarded.

c. POWER PROGRAM prints a report showing for each project and the system:

(1) Hourly, total and average generation.

(2) Load factors.

(3) An efficiency indicator.

Data as received from projects is checked and errors shown for correction interactively by an operator.

d. WATER PROGRAM prints a report showing for each project:

(1) Hourly and average discharges through power plant.

(2) Hourly and average discharges through outlet works or spillway.

(3) Head and tailwater elevations at 0700, 1500 and 2400 hours.

(4) Effluent water temperatures.

Errors are shown for correction interactively by an operator.

e. MRADS STORE PROGRAM stores selected data from the above programs in the Missouri River Automated Data System on the Boeing computer services computer:

(1) Project and system generation.

(2) Head and tailwater levels.

(3) Average daily power plant discharges.

f. AHOS POLL PROGRAM polls the Weather Service's AHOS data base in Medford, Oregon, for Missouri Main Stem and tributary river stages. Using data in MRADS discharges corresponding to these stages are found. Both stages and discharges are then stored in MRADS for later use in daily forecasting studies.

AIRBORNE LASER VALLEY/STREAM CROSS-SECTION DATA COLLECTION

John G. Collins
U. S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

William B. Krabill
National Aeronautics and Space Administration
Wallops Island, Virginia

ABSTRACT

With the cooperation of the National Aeronautics and Space Administration (NASA) and the Naval Research Laboratory (NRL), Washington, D. C., the U. S. Army Engineer Waterways Experiment Station (WES) is investigating the feasibility of obtaining cross-section data from airborne remote sensing systems. Eleven test profiles in the Wolf River Basin near Memphis, Tennessee, were selected. Each profile was characterized using conventional ground survey methods, and under "leaves-off" conditions, photogrammetric, airborne laser, and airborne radar data were obtained. For the airborne systems, automated procedures were developed by the NRL and/or NASA to account for aircraft motion effects. To date, results indicate that valley profiles can be accurately characterized with an airborne laser system. System problems precluded a comprehensive evaluation of the radar at this time. "Leaves-on," data reduction, and economic aspects are still to be addressed.

1. INTRODUCTION

Hydrologic-hydraulic (H&H) simulation studies of river basins in the United States constitute an important activity of the Corps of Engineers, other government agencies, and the private sector. Within the overall simulation process, the modeling of basin geometry is one of the more costly and time consuming facets involved. In 1978, the WES was authorized by OCE to investigate current practices involved in the acquisition and handling of cross-section data and to seek out improved methodologies. The effort discussed herein involves the test and evaluation of airborne remote sensing systems for the collection of valley and stream cross-section data.

2. TEST PROFILES

The WES completed a comprehensive H&H simulation study of the Wolf River Basin, northwest Mississippi and southwest Tennessee, just prior to the initiation of the investigation. This basin was selected as a test area because (a) the cross-section data obtained by remote means could be evaluated in terms of their impacts on flow lines estimated with the H&H simulation model available; (b) a variety of topographic, vegetation, and land use conditions existed in the basin; and (c) the necessary aircraft support facilities were readily available at Memphis.

Eleven test profiles were chosen; their approximate locations are shown in Figure 1. Seven of the profiles were at valley and stream cross-section locations previouFly established by the Memphis District (MD) and for which ground truth data were available. The remaining four profiles were not stream related but were chosen because of associat :d topographic, vegetation, and/or land use features.

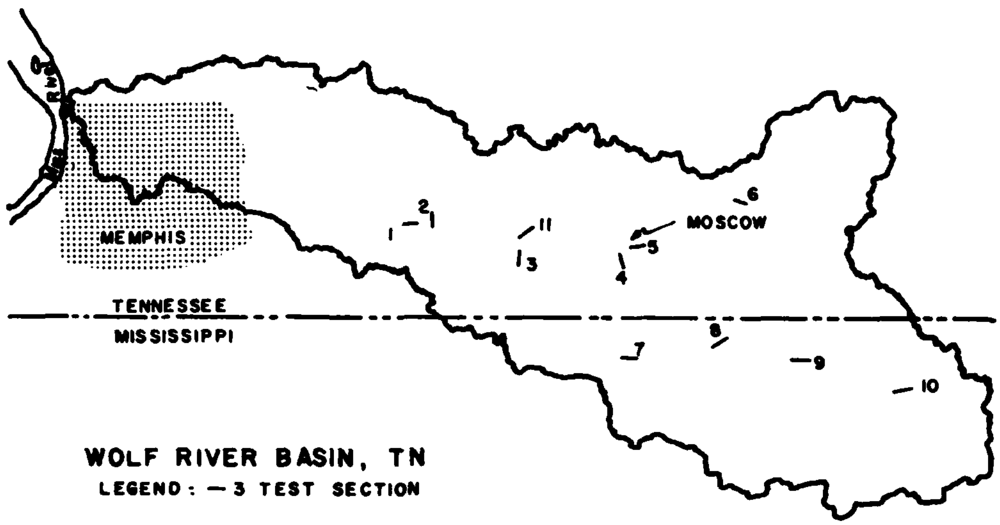


Fig. 1: Test profile locations

3. SENSORS

Sensors, aircraft, flight crews, and technical personnel were provided by both the NASA and NRL. The NASA remote sensing device is a conically scanning, neon (wavelength of 540.1 nm), pulsed laser system with a 400-pps data rate capability. Although designed primarily for oceanic bathymetry and laser-induced fluorescence studies, it can be used over land to simultaneously monitor forest canopy and ground profiles. As indicated in Figure 2, the pulse is partially reflected back to the receiver with the first return being indicative of the canopy surface.

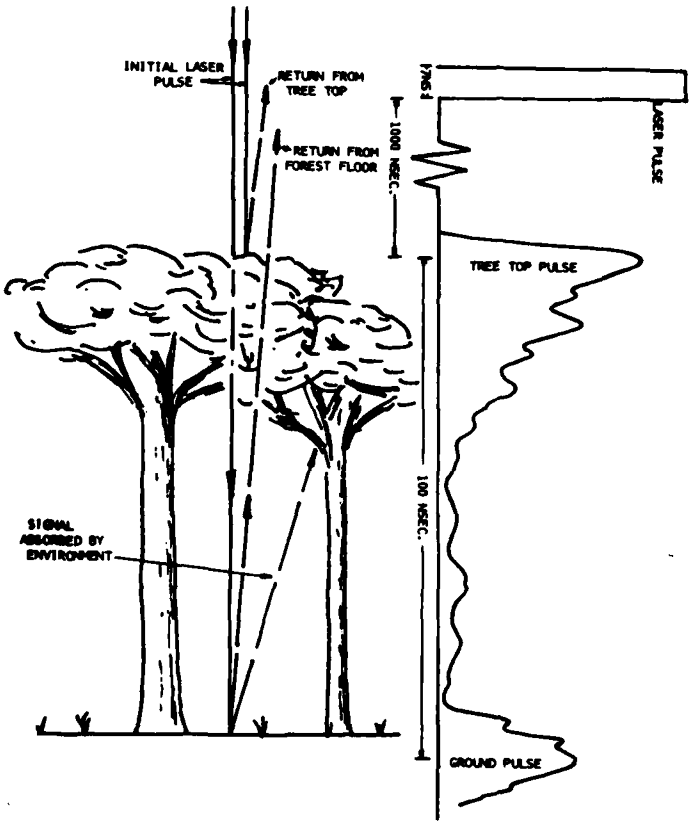


Fig. 2: Pulse analysis concept

All subsequent partial returns from the same transmitted pulse are ignored except the last return, which is compared to the ground level predicted on the basis of the previous pulse. If the last partial pulse yields a ground level within some preset edit limit (generally 2 m), it is accepted as a valid measurement; otherwise, it too is ignored. If the pulse is not fragmented, the single return is considered indicative of the ground or canopy surface depending upon whether or not it falls within the preset edit limit.

The NRL aircraft carried both a laser profilometer and a radar altimeter. The laser is a nonscanning, 904-nm pulsed system with a pulse repetition rate of 1000 pps but with a data-rate capability of only 200 pps. The system was designed to measure the range of a single reflecting surface, i.e. the ocean surface. Therefore, the first leading edge of a return pulse that exceeds a preselected threshold level is considered indicative of the distance from the laser to the reflecting surface. As presently configured, only one measurement per transmitted pulse is processed; consequently, it is not possible to simultaneously measure both vegetation and ground profiles with this system.

The NRL radar operates at a frequency of 10 GHz (wavelength of 3 cm) in a continuous wave mode. However, the generated signal is chopped, thus producing output pulses with selected durations and intervals. The signal receiver is preset for a given range-detection window to allow descriminate analysis of return signals. If ranges vary beyond the threshold values, erroneous results are produced.

4. FIELD TESTS

Five sets of data or imagery were obtained in the field: (a) NRL laser, (b) NRL radar, (c) NASA laser, (d) MD air photo, and (e) WES ground survey. Procedures followed are briefly discussed in the following paragraphs.

For the aircraft flights, balloons and aluminum foil were used to mark the profiles. Balloons were helium filled to about 1 m in diameter and guyed about 25 m above the ground. In addition, 30 aluminum foil patches about 40 cm square were layed out at 3-m intervals on the ground normal to and at the ends of each profile.

The NRL flight was made in December 1978. The nominal flight altitude was 450 m; coverage was made between 1300 and 1400 hrs; and the sky was clear.

NASA flights were made on two consecutive days in March 1979. From four to eight passes were made over each profile at nominal altitudes of 150- or 300-m. Coverage was made between 0900 and 1100 hrs and 1300 and 1500 hrs; the weather was clear and fair.

At the same time NASA flights were made, the MD obtained stereo aerial photographs. Photos were taken with a 6-in. (15.24-cm) focal length camera at a nominal altitude of 450 m.

Ground surveys (tape and transit) of the test profiles were made in July 1979. Three sets of data were obtained: (a) for those profiles not previously surveyed by the MD, station-elevation points were taken at about 30-m intervals and at topographic breaks; (b) elevation control points were taken at selected identifiable points along the laser transects; and (c) selected elevations and horizontal distances were obtained for use as photogrammetric controls.

5. RESULTS

Unprocessed data for the various sensors, test profiles, and passes were plotted. Visual examinations of the plots and comparisons of the plots with one another and with available ground truth data indicated the following:

a. Both the NASA and NRL laser systems sense microgeometric surface features. This was evident by the appearance of ditches, bushes, fence posts, etc., on the profile plots. A good example of this is shown in Figure 3, a profile taken at Moscow, Tennessee (profile 5), where buildings, cars, and trees were clearly portrayed.

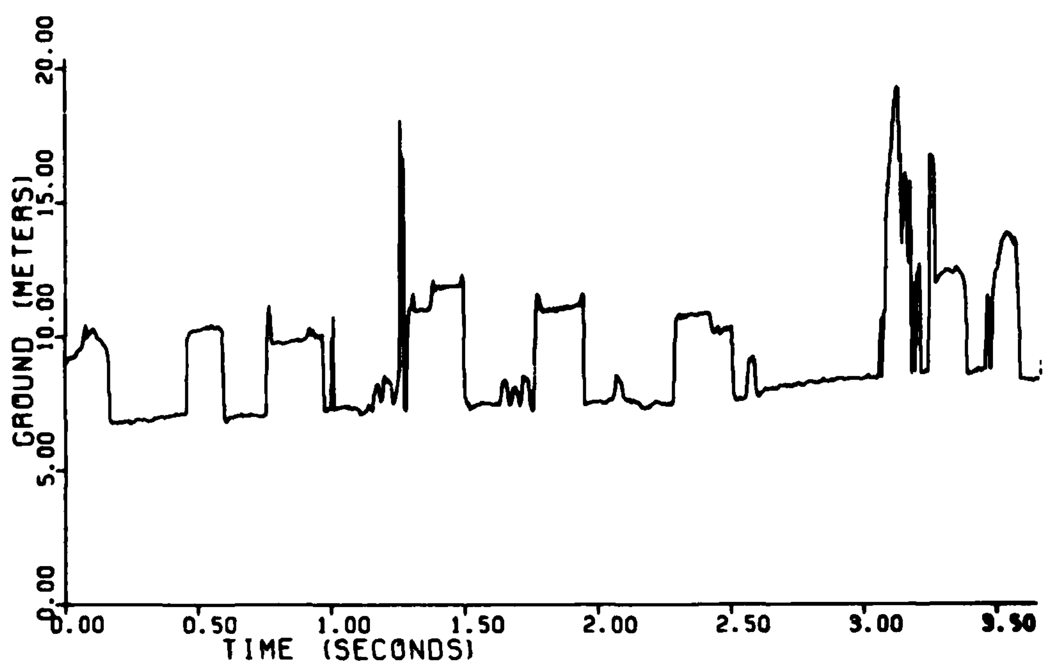


Fig. 3: Profile 5, Moscow, TN

b. The NASA system provides a high degree of repeatability. This is demonstrated in Figure 4, where plots of data for three separate passes over profile 2 show essentially the same surface features.

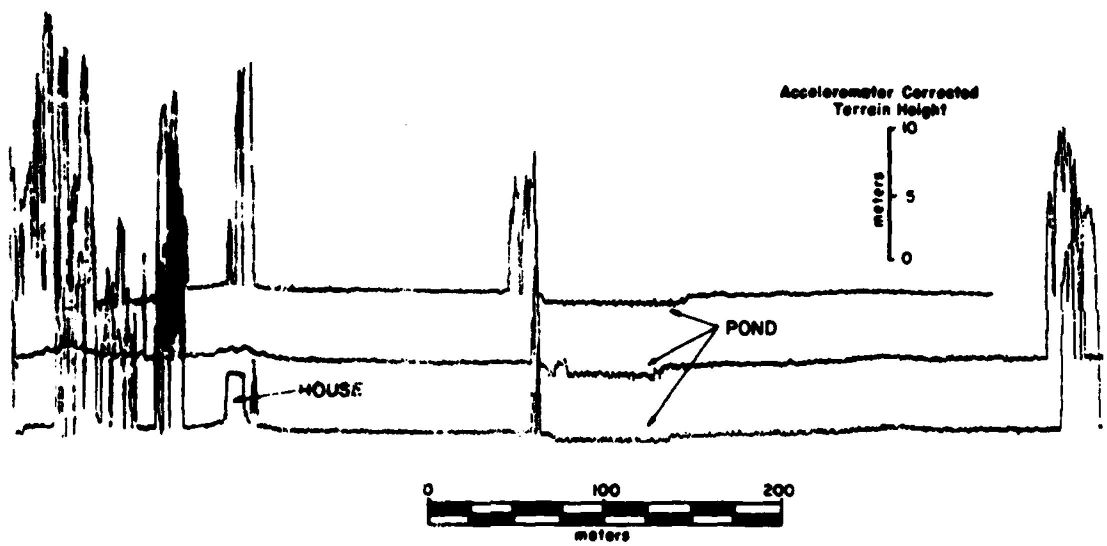


Fig. 4: Profile 2, Collierville, TN

c. Both laser systems provide macrogeometric information. When compared with available ground truth data, however, it was evident that the unprocessed records included significant distortions due to aircraft motion effects.

d. The ranges of altitudes (150-300 m), divergence angles (0-15 mR), and field of view angles (4-15-mR) tested by NASA had little impact on the quality of output data.

e. In general, macrogeometric features were evident in plots of NRL radar data; in some cases, however, range gating was such that valley floors were not included in the data records.

Radar data obtained were not considered suitable for futher analysis.*

---

* Radar data taken by the NRL over the Great Dismal Swamp, Florida, during 1979 were of a much higher quality and suggest that additional radar feasibility tests are warranted.

Efforts have continued in the analysis of laser data, though.

As noted in (a) above, distortions existed in the data records. To compensate for the effects of aircraft ground speed, pitch, roll, and altitude, software routines that could function off data records from the inertial guidance system were developed. Thus far, corrections have been made to several of the NASA laser profiles. For two profiles, 7 and 9, comparisons have been made with their photogrammetric counterparts; results are shown graphically in Figure 5 for profile 7. From Figure 5, it is apparent that a high degree of correspondence exists between the laser and photogrammetric profiles; the same is true for profile 9.

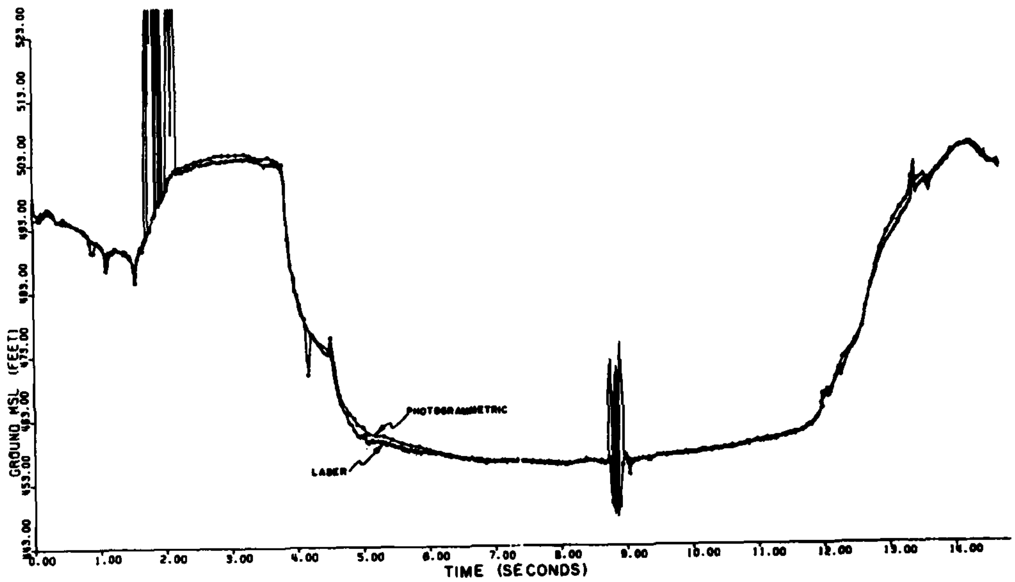


Fig. 5: Profile 7, Early Grove Creek, MS

Preliminary quantitative evaluations of the two profiles have also been made. On the basis of about 170 observation points, the root mean square (RMS) of the differences between laser and photogrammetric measurements was 27 cm for profile 7. Profile 9 includes both relatively open and heavily wooded segments. Based on about 70 observation points in the open and wooded segments, the RMS values were 12 and 50 cm, respectively.

As previously discussed, results to date are not conclusive insofar as the radar is concerned. With reference to the laser, however, available in-hand evidence strongly supports the technical feasibility of using the laser for the acquisition of cross-section data. Additional efforts will be required before the utility of a laser system is conclusively established.

6. FUTURE EFFORTS

Analyses of available NASA and NRL laser profiles must be conducted. Included in this task are removal of aircraft motion effects from data records, compilation of photogrammetric profiles, and statistical comparisons of laser and photogrammetric measurement differences.

Completion of the analyses will provide the means for evaluating the laser systems under "leaves-off" conditions. A similar effort must be made for "leaves-on" conditions. Flights to obtain the required data are to be made during the summer of 1980.

Presently, the NASA system does not adequately screen out small plants from the ground surface profile. This short fall is of some import if the masking effect of riparian vegetation on the geometries of stream channels is to be accounted for.

An automated means for reducing the number of laser observation points by about two orders of magnitude must be developed. Efforts to accomplish this have already begun.

Finally, the economic feasibility of obtaining, compiling, and using laser cross-section data must be evaluated.

AIRBORNE LASER HYDROGRAPHY

David Enabnit
Gary Guenther
Tim Rulon

National Ocean Survey
National Oceanic and Atmospheric Administration
Rockville, Maryland 20852

The National Ocean Survey (NOS) has been investigating airborne laser hydrography since 1970. The objective of that work was to determine if the technique could perform accurate hydrographic surveys at a significantly reduced cost and with significantly reduced manpower.

The airborne laser hydrographic technique uses an aircraft-mounted, pulsed laser system to collect a swath of discrete soundings along each flight line. It measures water depth exactly like a sonar; using light instead of sound. The NOS operational system will take 600 soundings per second over a 200-meter wide swath with an average distribution of 1 per 25 m^2. The system will operate from a light, twin-engine aircraft flying at 300 meters and 75 m/sec. The laser will have a green wavelength for maximum water penetration and will be totally eye safe for bystanders in the survey area.

As part of the NOS investigation, the major benefits of airborne laser hydrography were identified and quantified. The cost of laser surveying was modeled and compared to historical costs for launch-based sonar surveying. It was concluded that laser hydrography could be performed for one-sixth the cost of launch hydrography on a per-unit-area basis. A similar analysis showed that laser hydrography required only one-fifth the manpower of launch hydrography per unit of area surveyed. Other major benefits were the ability of a single laser system to survey more area annually than the entire NOS launch fleet, and a 300-fold increase in the number of soundings per unit area.

A series of experiments and analyses were performed to establish that the airborne laser could measure water depth to within the NOS accuracy standards. 1.5 million airborne laser depth soundings were collected in 1977 using a prototype system belonging to NASA. These laser-measured depths were compared to sonar-measured depths of the same area, and it was determined that the accuracy of the NASA system was 6.4" ± 4". For comparison, the NOS accuracy standard is 12".

Laser hydrography is an optical technique and the depth of penetration will be limited by water clarity. Water clarity data was gathered from oceanographic data archives and an assessment was made of the amount of area that could be surveyed by laser. These "surveyable areas" were then compared to the NOS hydrographic survey requirements to determine the applicability of the technique to NOS needs. It was determined that an enormous amount of area is surveyable by laser and that these are areas for which NOS has an established survey requirement. Depths of 60 to 90 feet should be typical for the NOS operational laser system along the mid-Atlantic coast.

Laser operations were studied to see if the anticipated benefits would remain after practical aspects of laser hydrography were considered. An operational scenario and the NOS experiences during the 1977 field experiments were used in this study. It was concluded that the technique is straightforward to use and does not require hard-to-get information to manage and operate.

Potential impacts of airborne laser hydrography were investigated to see if the savings gained in data acquisition would be lost elsewhere in the chart production system. The largest single impact would be caused by the enormous increase in the amount of hydrographic data to be processed, verified, and used. This impact will be minimized by continuing the present NOS trend towards automated data handling and processing.

Based on the encouraging results of these investigations, the National Ocean Survey has decided to proceed with the development, fabrication, and implementation of an operational airborne laser hydrography system.

Work will begin in FY 1980. The development of the positioning subsystem and the hydrographic software and data processing subsystem will be the focus during FY 1980 and FY 1981. In FY 1982, work on the laser subsystem will begin. System completion is scheduled for FY 1984.

For further information contact Dave Enabnit (301) 436-6906.

SEASAT: A NEW REMOTE SENSING TOOL IN SPACE

D. LICHY

U.S. Army Coastal Engineering Research Center
Fort Belvoir, Virginia 22060

ABSTRACT

SEASAT was the first satellite to have on board a Synethic Aperature Radar (SAR). During its short mission (3 months) it collected excellent imagery over land and ocean. To be presented are examples of the imagery with land and ocean analysis. The land applications are geology, land-use, fracture analysis, and flood monitoring. The ocean features are wave direction and length, current patterns, shoaling and wind speed analysis.

SEASAT was launched on 26 June 1978 and had a power failure on 9 October 1978. During this time the Corps of Engineers conducted a ground truth experiment at the Coastal Engineering Research Center's, Field Research Facility, Duck, North Carolina. This data is presently being analyzed but preliminary results will be presented on the accuracy of the SAR for oceanographic and coastal engineering phenomena.

This research effort for the analysis of SEASAT data will provide the Corps of Engineers with insight for future usefullness and requirements of the active microwave satellite systems.

THE USE OF AIRBORNE SPECTRORADIOMETER DATA FOR EVALUATING WATER QUALITY

Harlan L. McKim
Carolyn J. Merry

U.S. Army Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire 03755

Robert W. Layman

Dartmouth College
Hanover, New Hampshire 03755

ABSTRACT

A 500-channel, 0.4 to 1.1 μm, airborne spectroradiometer* has been tested to evaluate its usefulness as a remote sensing device to quantitatively measure water quality rapidly and efficiently. Field tests coordinated with ground truth sampling were done over reservoirs, rivers, estuaries and open ocean. Laboratory tests were run with known concentrations of clay suspensions and algae. The problem of specular reflection from wave-roughened surfaces was also studied during the laboratory tests.

Although the limits of sensitivity of the instrument are not yet known, it was found that qualitative and quantitative measurement of turbidity within a water body is possible. Also, inorganic and organic constitutents can be differentiated. Future work will explore the use of theoretical models and algorithms in data reduction to improve the reliability and sensitivity of the airborne spectroradiometer system.

* Chiu, H. and W. Collins (1978) "A Spectroradiometer for Airborne Remote Sensing," Photogrammetric Engineering and Remote Sensing, Vol. 44, No. 4, pp. 507-517.

USE OF THE GOES DCP BY THE CORPS OF ENGINEERS*

Timothy D. Buckaloo
U. S. Army Corps of Engineers
New England Division

H. L. McKim
Water Resources Support Center
Fort Belvoir, Virginia

The New England Division Corps of Engineers working with private industry has demonstrated the random reporting capability for collecting data using a standard 1500 hz channel on the NOAA GOES satellite. The new mode has several advantages over scheduled or interrogation modes used to collect hydrometeorological data required in reservoir regulation. The need for this data is especially critical during severe weather and flood situations, and a data collection system should be responsive to critical events. Previously, available satellite systems of data collection have not sufficed for smaller watershed and applications in New England. In the random reporting system, hundreds of data collection platforms transmit on a single channel at proper time intervals to insure an acceptable probability of reception. Several techniques have been incorporated to improve reception probabilities, the main one being a short message (less than 2 seconds) and an adaptive algorithm programmed into each platform. This algorithm assures sufficient transmission during critical times yet relieves the system of superfluous messages during normal periods when no new or important information has been generated. The demonstration has confirmed that even without the adaptive feature, at least 200 platforms will report successfully (with 90% probability) within an hour; and that research has revealed future enhancements which could increase the number of platforms by an order of magnitude. A new platform designed around readily available components is now operable and is expected to bring equipment costs within reach of many users.

The poster shows how this system operates and performs and the cost associated with this operation. The computer software and algorithms used to acquire sufficient data transmissions during these critical times will be shown. The use of the data in the operation of the New England Division Water Control Center will be presented. In addition, other hydrologic and environmental sensors that have been interfaced to the data collection system will be discussed.

*(GOES DCP) - Geostationary Operational Environmental Satellite Data Collection Platform

USE OF SIDELOOKING AIRBORNE RADAR (SLAR) AT THE LIBBY PROJECT, MONTANA

Richard W. Galster
Chief, Geology Section, Seattle District
Seattle, Washington

ABSTRACT

Regional geologic structure was studied at great length for seismic evaluation of Libby Dam and its proposed companion reregulating dam. A paucity of regional structural mapping prior to this study required use of several aerial imagery methods in order to obtain adequate data on the regional structural fabric over an area of 20,000 square kilometers, and select areas for special ground struy. As much of the region is covered by open forest, SLAR imagery together with analysis of ERTS and conventional high altitude aerial photography was used to complete the regional areas.

CALIFORNIA COASTAL REMOTE SENSING

DOUGLAS M. PIRIE

U.S. Army Corps of Engineers
San Francisco District
San Francisco, California 94105

The author has explored the use of aerial remote sensing techniques to identify the various coastal and estuarine processes that impact the California coastal environment. The poster presentation primarily covers the use of photographic techniques; however, the use of thermal and multispectral scanners and side looking airborne radar (SLAR) has also been utilized and may be discussed.

Specific examples covered will include San Francisco Beach and Bar wave refraction, crenulate bay structures, San Francisco Bay currents and waves, Bolinas Lagoon estuarine processing, nearshore bottom imaging and Humboldt Bay coastal currents.

PORTLAND URBAN AREA WILDLIFE HABITAT AND LANDSAT DEMONSTRATION PROJECT

S. Holmes, R.K. Dodge
U.S. Army Corps of Engineers-Portland District
Portland, OR

ABSTRACT

A remote sensing test project is currently being conducted with Battelle Northwest Labs to compare computer classification of landcover from Landsat (MSS) imagery with manual classification techniques utilizing large scale photography.

This project was initiated to compare and contrast two land-cover classification techniques. The Portland - Vancouver Metropolitan area was initially classified manually to map a variety of wildlife habitat zones.

A cooperative computer interactive classification project was later set up with Battelle Pacific Northwest Laboratories in order to compare interpretative accuracy, consistency in classification and overall costs of production with the manual method. This pilot project will help determine feasibility of future computer interactive projects.

SALMON SPAWNING GROUNDS MONITORING

R.K. Dodge, S. Holmes
U.S. Army Corps of Engineers-Portland District
Portland, OR

ABSTRACT

Photogrammetric techniques were used to locate salmon redds (spawning nests) associated with the Lost Creek diversion tunnel. Resultant maps were used to locate irrigation equipment to minimize loss of salmon eggs during closure.

The purpose of this project was to survey the extent of Chinook salmon spawning activity on the Rogue River from the fish barrier dam at Cole Rivers Fish Hatchery(river mile 157) to Elk Creek (river mile 152) and to survey the extent of exposure of salmon spawning areas following closure of Lost Creek diversion tunnel.

The objective of the survey was to determine the location and numbers of individual salmon redds (spawning nests). Redds are depressions scooped in the gravel by spawning salmon in one to several feet of water. Individual redds are two to three feet wide and four to six feet long. In areas of intense spawning they may overlap one another. They are apparent to the observer as the disturbed gravel appears lighter in color. This difference is apparent in color photographs. Disturbed gravel is not covered with algae as is adjacent gravel so that contrast may be increased with infra-red film. The ability to penetrate water is also a prime consideration. Redds in less than three feet of water are of primary significance in the survey.

Location of redds were digitized and mylar-base plots were made that can be used as overlays on line drawings or photo mosaic base of this reach of the river. An overlay of the altered shoreline resulting during closure was also prepared so that it is possible to readily determine the number and percent of redds exposed. This information was used to site irrigation equipment to keep salmon eggs moist during closure and to determine the number of redds affected by the change in water level as the basis for any compensation for losses.

DEPOE BAY KELP BED MONITORING

R.K. Dodge, S. Holmes
U.S. Army Corps of Engineers-Portland District
Portland, OR

ABSTRACT

Photogrammetric techniques were used to monitor the distribution and density of kelp beds at Depoe Bay. This is an on-going project designed to determine dredging operation effects on kelp beds.

The inner harbor of Depoe Bay, which requires dredging maintenance every three to five years, will not permit the entrance of a hopper dredge due to the extremely narrow entrance channel. Therefore, a pipeline disposal system is utilized.

A typical dreding operation for Depoe Bay will take around three weeks, during which time 12,000 - 15,000 cubic yards of dreding spoils will pass from the disposal outlet into the outer Depoe Bay area. Although wave action seems to disperse the spoils rather quickly there is still concern for a possible negative impact on the bull kelp in the outer bay. There is a possible chemical effect due to the highly anaerobic state of the dredging spoils. Also, the hold fast of the kelp may be damaged by being covered by an accumulation of spoils material.

Enhanced color photography was flown to monitor the effects of this activity. (1:24,000 and 1:4,800) stereo photography was utilized to monitor the extent and density of the kelp beds. Large scale (1:1,200 of larger) stereo photography was used for the photo interpretation of the interidal area and the immediate adjacent subtidal area including near shore kelp. The flight was made on a day of calm sea surface conditions, low tide and minimum sun glare and reflectance for maximum kelp/water contrast also greater water penetration.

The appearance of the bull kelp was obvious in all of the three scales of photography by their tone and shape. Two general areas existed where interpretation was limited: Close to the rocky shoreline were small rocks and different species of plant life easily confused with bull kelp, and; in areas of dense white caps no interpretation was possible.

Kelp location were digitized on a Wild B8 stereoplotter interfaced with a programmable calculator and a 9 track magnetic tape drive unit. The data was processed on an IBM 360/50 with an in-house computer program (PHOTODIG).

Portland District produced a report on this study: <u>Intertidal Disposal of Dredged Materials as Depoe Bay, Oregon</u>: <u>An Analysis of Effects</u>, October, 1978.

PREDICTION OF ARCHEOLOGICAL SITES: RECONNAISSANCE SURVEY OF THE LOWER PUERCO AND SALADO DRAINAGES, NEW MEXICO

Donna M. Roxey

U. S. Army Engineer District, Albuquerque
Albuquerque, New Mexico

The objective of an archeological reconnaissance survey in the Corps planning process is to assess the relative impacts on archeological resources of each project alternative considered in Phase I, state 2 planning.

Traditionally when archeologists were asked to perform a reconnaissance survey for the Corps, they would compile a list of known sites from state files and review the readily available literature. Often these activities would be followed by a casual field inspection which might discover a number of previously unrecorded sites. These sites would usually be plotted on a topographic map and the site, to some degree, would be described. On the basis of all information gathered, archeologists would advise the Corps as to the relative likelihood that implementation of their project alternatives might result in positive or negative impacts to important archeological resources.

Such a procedure is not cost-effective and can scarcely be termed scientific. It cannot be tested for reliability since it is not replicable. Quantified information is rarely obtained and no testable hypotheses are generated. Later, if an inventory survey is required, virtually every aspect of the reconnaissance study will need to be repeated or supplemented.

Due in large measure to pressure from the Federal sector, particularly the Corps, and a desire by many in the archeological profession to scientifically tackle the assessment problem, more reliable procedures are being developed and tested by several individuals and institutions throughout the country.

The poster presentation before you illustrates a reconnaissance survey procedure being developed by Mark Wimberly and Peter Eidenbach, Human Systems Research, Inc. (HSR), of Tularosa, New Mexico. It is currently being used for a reconnaissance study of the lower Puerco and Salado drainages in central New Mexico. This work is being performed for the Albuquerque District, COE, in connection with its Phase I planning studies.

The procedure being tested by HSR is based on the assumption that archeological sites and environmental factors will pattern. By use of existing data and Landsat imagery, the study area is stratified into environmental zones. A statistically reliable sampling design is developed which will uniformly sample within each identified zone. Field execution of the design will obtain all important site information and ground truth the environmental stratification. The results of the procedure will be to produce sound baseline data for future studies and probability statements for the distribution, density and occurrence of particular kinds of archeological sites within impact zones of project alternatives. Neither individual sites nor the samples areas will require revisitation for future inventory purposes. The sample design is replicable and statistically reliable.

The following paragraphs provide a brief description of the use of Landsat imagery in the stratification of the study area. This description is reproduced from a preliminary report provided by HSR before it began field operations.

THE SAMPLING DESIGN AND KNOWN CULTURAL RESOURCE LOCATIONS

By Eileen Camilli

Sampling Design

Sampling of the Puerco and Salado project areas is based on a surface cover-type stratification. Mapping procedures utilized Landsat imagery as the primary data source in production of the stratification. Imagery acquired for production of the surface cover-type map consists of a false-color composite Albuquerque scene taken on October 25, 1975. This image has undergone computer enhancement through the U.S. Geological Survey EROS Digital Image Enhancement System (EDIES) and provides optimum display of terrain information. The scene provides coverage of both the Puerco and Salado Drainages above the confluence of each with the Rio Grande.

Surface cover-type delineation was produced by visual photointerpretation of a false-color composite paper print at a scale of 1:250,000. Surface cover-type boundaries were first drafted onto an acetate overlay. Boundaries were then transferred from the overlay to a project base map with the use of a Bausch and Lomb Zoom Transfer Scope. The project base map is at a scale of 1:48,000 and consists of the area covered by 7 USGS 7.5' quadrangles and portions of a 7.5' and a 15' quadrangle listed below:

USGS Topographic Quadrangles
Belen NW, N.M.
Belen SW, N.M.
Veguita, N.M.
La Joya NW, N.M.
Abeytas, N.M.
San Acacia, N.M.
Rio Puerco, N.M., portions of T6N, R2W and T6N, R1W
Riley, N.M. 15' quad southern ½
La Joya, N.M.

Eight surface cover-types were defined for the proposed Puerco dam site and flood-pool, and seven for the Salado. Zones have been given alphabetic designations prior to field reconnaissance by an ecologist. Survey by the ecologist will enable identification of vegetation cover, soils and physiographic characteristics of each zone. Prior to field reconnaissance, however, each zone was inspected on 1:48,000 quadrangle reduction sheets for differences in relief. The results of this inspection and of visual interpretation from the imagery are listed in Table 5.

Differences between zones O, P and M in this table are probably due to vegetation cover rather than physiography. Due to their small size, zones G in the Puerco project area and H in the Salado project area are not figured into the first stage sample. Field reconnaissance will determine whether these zones will be sampled separately.

A first-stage sample was chosen on the basis of the sampling stratification. Sample unit size was set at ¼x¼-sections, assuring a relatively large number of total units to be sampled, as well as economy of field time. English measure units were used because survey monuments could in some cases be used as locational aids in the field; ¼x¼-sections are, however, very close to 400 meters on a side.

Table 5

STRATIFICATION ZONES

Zone	Mapped Information	Image Texture
	PUERCO PROJECT AREA	
B	Talus slope, western exposure	Rough
C	Talus slope, western exposure	Medium
D	River floodplain and drainage channel, relatively flat	Smooth
E	River floodplain and flats	Smooth
G	Relatively flat area, could be included with Zone E	Smooth
H	Higher elevation *flats*, gentle slope	Smooth-medium
J	Talus slopes, eastern exposure; northern and southern exposures on tributary drainages	Rough
K	Tributary drainage channels (not as much deciduous growth as in Zone D)	Smooth-medium
	SALADO PROJECT AREA	
D	Salado and tributary drainage channels	Smooth
H	Higher elevation *flats*, just above talus	Smooth-medium
H'	Higher elevations, gentle slope	Smooth-medium
M	Canyons and slopes	Rough
N	Mountains	Rough
O	Talus slopes	Rough
P	Canyons and talus	Rough

A 3 percent sampling proportion was chosen for the first stage sample. The purpose of a first-stage sample is to test the reliability, in empirical terms, of the sample stratification, as well as to inform general patterns in an area which might require modification of the stratification used in the second sampling stage. Within each stratum, units were apportioned as shown in Table 6, in direct proportion to stratum area.

Deviations from an exact 3 percent sampling fraction arise from the assignment of at least two sampling units to each stratum, regardless of its size, so that variances and standard deviations can be calculated on the basis of the first-stage sample. These statistics will be used to apportion the second-stage, 7 percent sample on the basis of variance in sampled parameters rather than stratum area.

Table 6
THREE PERCENT SAMPLING PROPORTION

Zone	Area (km^2)	3% Sample Area (km^2)	Number of ¼x¼ Sections	
		RIO PUERCO		
B	17.48	.52	3	
C	31.33	.94	5	
D	32.17	.97	6	
E + G	14.90	.45	3	
H	8.32	.25	2	
J	36.56	1.10	6	
K	4.37	.13	2	
	145.13	4.36	27	(= 3.01%)
		RIO SALADO		
D	8.96	.27	2	
H + H'	7.92	.24	2	
M	56.59	1.70	6	
N	1.55	.05	2	
O	2.07	.06	2	
P	6.57	.20	2	
	83.66	2.52	16	(= 3.10%)

Sample units were mapped using 1:48,000 base maps upon which the sampling stratification had been transferred. Within each stratum, ¼x¼-section squares which fell *totally* within the stratum boundaries were numbered, and those units to be sampled chosen randomly from each series. These ¼x¼-section units were then transferred to new base maps. They will also be enlarged to 1:24,000 scale and drawn on field topo sheets for use in the location of survey quadrats in both survey areas.

CORPS OF ENGINEERS ALTERNATIVE OPTIONS FOR ACCESS TO LANDSAT-D DATA

Lawrence P. Murphy
U. S. Army Engineer Topographic Laboratories
Fort Belvoir, Virginia 22060

ABSTRACT

This paper describes work performed by the Space Division of General Electric Company under contract to obtain trade-off determinations and analyses for an interface between the Corps of Engineers (CoE) and the advanced (Landsat Follow-on) NASA ground data distribution system. This effort was performed to define hardware, systems options and rough order of magnitude cost figures for accessing wideband, multispectral Thematic Mapper (TM) digital data for Corps Civil Works remote sensing applications. Since the TM that is planned for use on the upcoming (1981) Landsat-D will have significantly better spatial and spectral resolution than the current Landsat system, the Corps anticipates a much greater use of these data toward solving many of its remote sensing mission problems. Data output from the TM scanner will be seven times greater than from the current Landsat multispectral scanner. Thus, the Corps also predicts that data accessing and handling problems will multiply. The contractor analyzed Corps' requirements, defined probable uses of the Landsat-D data, and subsequently predicted that the Corps would need approximately 2000 TM scenes per year. TM data for flood damage assessment or for use under the Permits Program were determined to be needed within 48 hours after acquisition by the satellite. Seven access points were identified where the Corps could make direct or indirect data taps into the Landsat-D data distribution system. Hardware options and costs were developed for each of the data access points. Costs and hardware estimates were also developed for redistributing the data from the preferred main data access point to a single Corps' data reception and processing facility in the Washington Metropolitan area. Key issues were also characterized on the acquisition of data from EDC, Sioux Falls or directly from NASA Goddard Space Flight Center.

AN INTEGRATED TERRAIN ANALYSIS SYSTEM

A. R. Pearson
T. C. Vogel
J. S. Wright

U. S. Army Engineer Topographic Laboratories
Fort Belvoir, Virginia 22060

BACKGROUND

Historically, the U. S. Army has relied on standard topographic maps and special terrain reports to provide commanders with the terrain information necessary for effective planning of military operations. In an effort to provide better terrain information in less time, the U.S. Army Engineer Topographic Laboratories (USAETL) is developing the Topographic Support System (TSS), a self-contained unit designed to give total topographic support in the field when short response time is essential. The TSS is composed of several subsystems, one of which is the MGI (Military Geographic Information*) subsystem. This subsystem combines the previously separate functions of topographic mapping and collection of military geographic information. It will immediately respond to spot inquiries and quickly produce map-type terrain analyses.

Operational Concept. The operational concept of the MGI subsystem (Figure 1) relies on a preformatted thematic graphic data base (TGDB). The TGDB consists, in part, of a series of factor overlays, map-type graphic representations of specific terrain subjects drawn on transparent plastic (mylar) registered to a 1:50,000 scale topographic map. For each 1:50,000 scale topographic map in the area of operations there are factor overlays for terrain subjects such as soil, vegetation, slope, geology, surface configuration, and drainage. Some of these have supporting data tables. Figures 2 and 3 show what a vegetation factor overlay and supporting data table look like. Factor overlays from the TGDB are combined with or without the aid of a mathematical model to produce terrain analyses known as topic graphics like cross-country movement maps, field of fire maps, and others.

The data required for producing the factor overlays is derived from all available sources including imagery and is systematically accumulated by progressive interpretation and inference.

*Information on natural and manmade features which affect military operations.

MGI Subsystem Design. The four modules of the subsystem, physically housed in mobile vans for field use, correspond to the functional phases of the work; collection, information, analysis, and synthesis (Figure 4).

·The Collection Module is primarily concerned with the acquisition of source materials and only incidentally with direct acquisition of field data.

·The Information Module is the repository for both raw and processed MGI. Aerial imagery is held elsewhere, though it can be retrieved for use by this subsystem.

·The Analysis Module is where the most critical and time-consuming task of the entire terrain intelligence operation is performed; that of extracting, reducing, and recording information on the factor overlays to be filed in the TGDB.

·The Synthesis Module is where factor overlays are combined graphically, and sometimes mathematically, to predict terrain influences on selected military operations. The final outputs might be as simple as voice replies to telephone inquiries, or as complex as folios with multicolor maps and text. Usually, though, map overlays or map overprints will be the subsystem end products. The form of the outputs will depend on user requirements and immediacy of need.

Analysis Guide. Analysis guides are currently being prepared by USAETL to support the Analysis Module (Figure 5). These guides detail the techniques and sequence of analysis for each terrain subject, thereby ensuring that all available sources are fully exploited with a minimum expenditure of time and resources.

These procedures instruct the analyst to use all available sources because no single source can provide all required data for even a single terrain subject. Recognizing the heterogeneity of sources, the procedures allow for problems in integrating sources of varying scales, completeness, and reliability. Proper sequencing of analysis is emphasized to afford systematic accumulation of data by progressive interpretations and inferences.

Analysis of topographic and thematic maps is required early in the analysis process because basic data can be extracted quickly and easily, and potential location problems are eliminated. Map analysis procedures go beyond simple map reading and traditional methods of inferring terrain information from landform and drainage patterns and require the study of the map compilation specifications. The following examples illustrate the type of information that can be derived from compilation specifications:

·Single-line streams are less than 25 meters wide.

•"Woods" symbol includes trees over 3 meters high with canopy closure greater than 50%.

•Bridge symbols are drawn to scale when the symbol is longer than 1.5mm.

After the map analysis is completed, aerial imagery is analyzed to help fill information gaps. Imagery will most often be the primary source for specific information though imagery analysis is the most difficult and time-consuming of the analyst's task. Despite the efforts being made to automate the imagery analysis process, there is no complete system currently available that is suitable for field deployment; therefore, procedures for imagery analysis given in the guides are for manual methods (Figure 7).

Procedures for examining literature which supplement the other data sources are provided after map and image analysis.

Synthesis Guides. Synthesis guides being developed by USAETL will support the terrain analyst in the Synthesis Module of the MGI subsystem (Figure 6). They contain step-by-step instructions for selecting appropriate factor overlays from the TGDB, superimposing them, and combining them according to a simple mathematical model to produce a map-like topic graphic. These guides do not attempt to develop underlying theory. They simply show the analyst how to put preformatted data together. Precalculated constants and adjustments factors are provided in reference tables or nomographs where possible.

One such guide, the Synthesis Guide for Cross-Country Movement (CCM), instructs the terrain analyst to (1) select the soil, slope, vegetation, drainage, and surface configuration factor overlays from the TGDB, (2) manually trace them onto one complex overlay, (3) run the combined data through a preprogrammed calculator, and (4) categorize the resulting speeds into movement categories on the redrawn complex overlay which becomes the CCM topic graphic. The CCM topic graphic or map indicates the suitability of terrain for the movement of foot troops and vehicles. In this way, densely forested, steeply sloping terrain with loose soil might appear on the CCM map as a "no go" area for jeeps, but as "5 kph" area for foot troops.

Other planned synthesis guides include cover, concealment, helicopter landing zones, and fields of fire. Future versions of the synthesis module may replace manual methods with optical synthesizers and microprocessors, and replace full-sized working materials with microforms to reduce substantially the time time and labor for the synthesis phase.

SUMMARY

The U.S. Army Engineer Topographic Laboratories is developing a Topographic Support System (TSS) for the field Army that integrates the analyses of all available terrain information sources to produce quick-response products required by commanders. The data extraction and synthesis functions of the TSS are located in the MGI subsystem which has four modules. Two of these modules, the Analysis Module and Synthesis Module, are supported by procedural guides that provide step-by-step instructions for deriving data and putting this data together to show how terrain influences specific military operations. Commanders will use the quick-response products of the system to make tactical decisions.

The system illustrates the significant contribution of applied remote sensing to a valuable military tool. The total concept of this terrain analysis system with its analysis and synthesis guides can be used to solve civil as well as military problems thus creating expanded contributions for applied remote sensing.

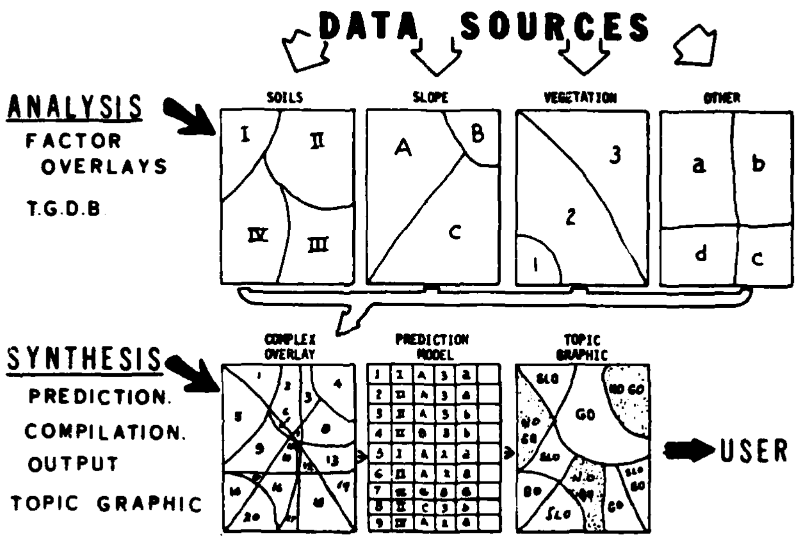


Figure 1. Operational Concept of the MGI Subsystem

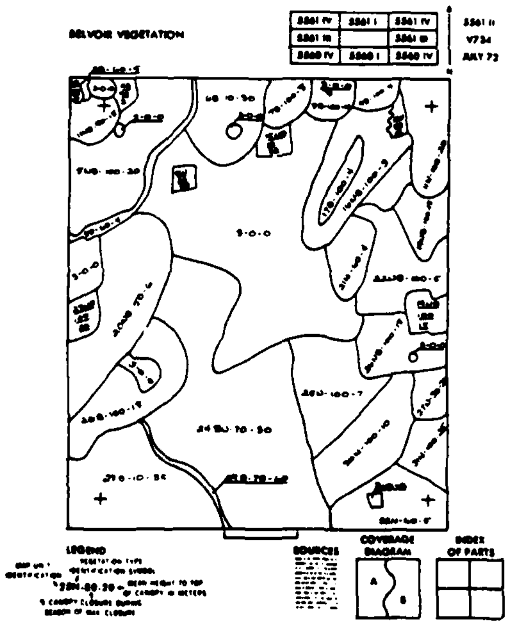


Figure 2. Vegetation Factor Overlay

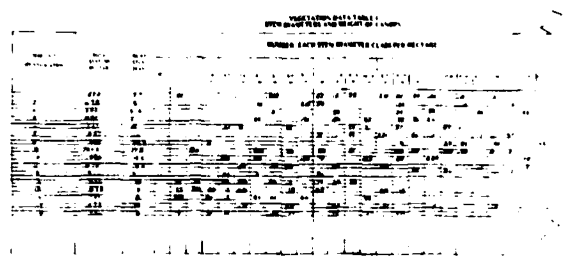


Figure 3. Vegetation Data Table

AD-A084 043 ARMY ENGINEER TOPOGRAPHIC LABS FORT BELVOIR VA F/G 17/8

U. S. ARMY CORPS OF ENGINEERS REMOTE SENSING SYMPOSIUM, 29 - 31--ETC(U)

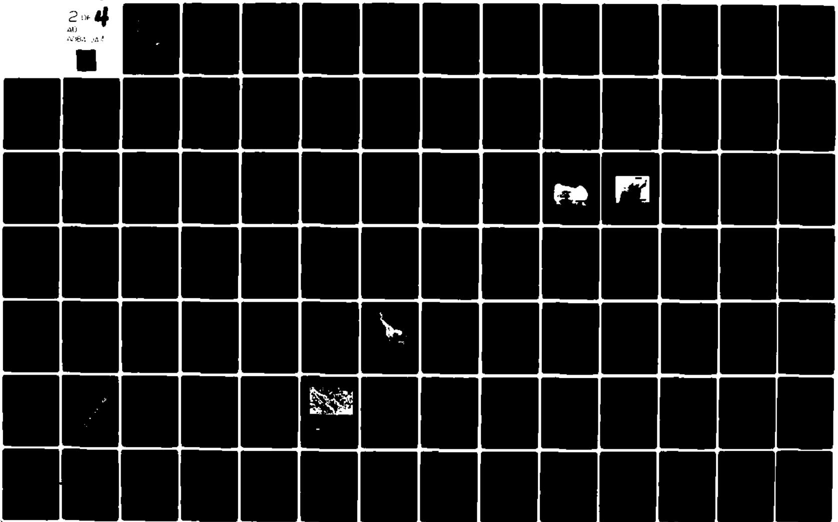
OCT 79

UNCLASSIFIED NL

2 OF 4

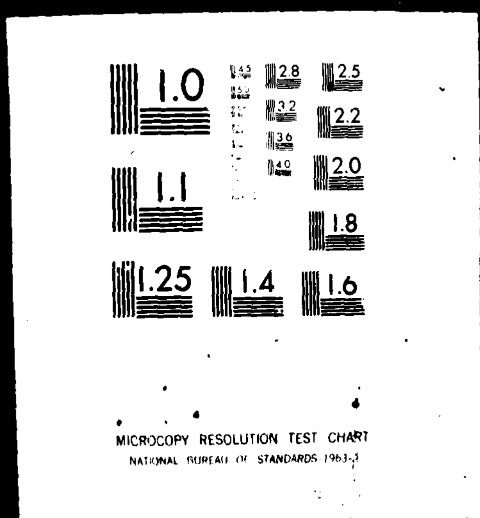
AD

A084 043



2 OF 4

AD
A084 043



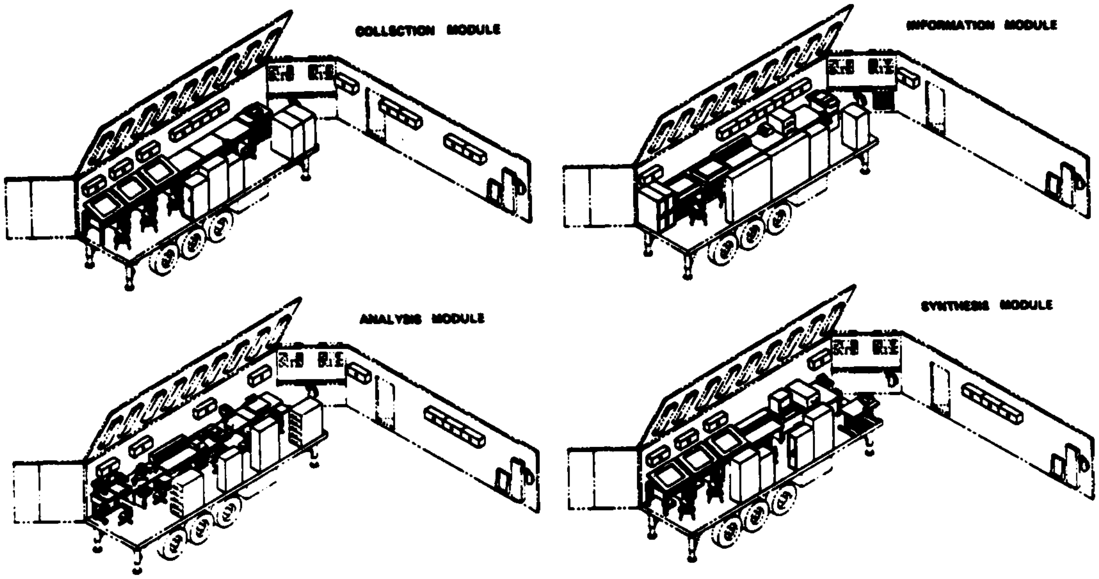


Figure 4. Van-mounted Modules of the MGI Subsystem

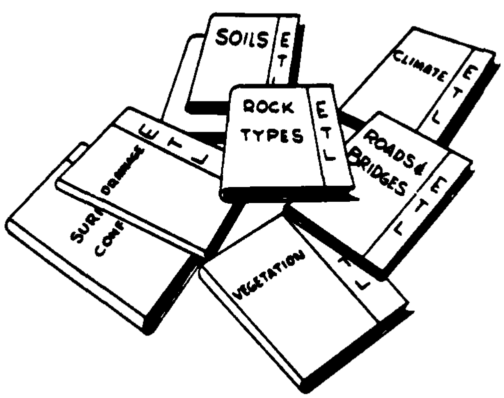


Figure 5. Analysis Guides

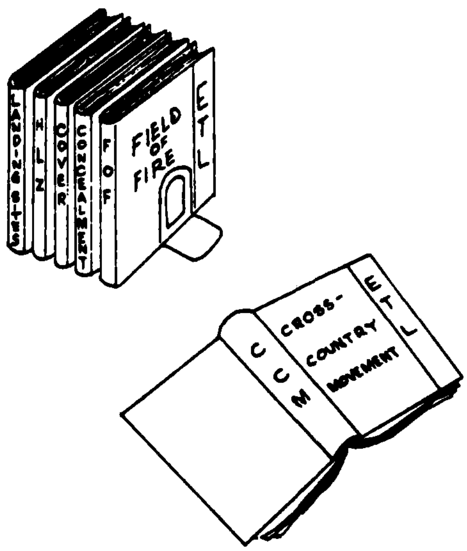


Figure 6. Synthesis Guides

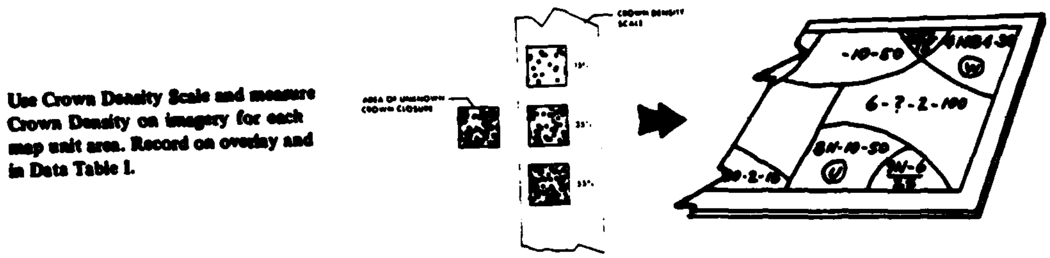


Figure 7. Determining and Mapping Canopy Closure Manually

PHOTOGRAMMETRY

By

A. O. Quinn, P.E.
Certified Photogrammetrist
QUINN AND ASSOCIATES
Horsham, PA

The purpose of this paper is to provide some basic background and an up-to-date review of the uses and applications of photogrammetric techniques in the solution of Surveying and Mapping problems. Photogrammetric methods can provide reliable solutions to many surveying and mapping projects, however, the constraints of weather, ground cover, foliation, sun angles and the personal abilities and qualifications of surveyors, photogrammetrists and flight crews, still impose some restrictions on the use of aerial and terrestrial photography in Surveying and Mapping. I have had the good fortune of participating in this most fascinating part of the Surveying and Engineering Profession for more than forty years, and I have witnessed a steady and profound growth in the application of fundamental photogrammetric principles and the development of precision instruments which can be used in abstracting and mapping the vast amount of data contained on photographs.

There are some Engineers, Surveyors and Laymen who cannot believe that precise maps can be produced through the use of aerial photographs. The number of skeptics is decreasing rapidly. Some have been converted when they have made cost comparisions between ground surveys and combined ground and photogrammetric methods; others have realized that important savings in time are possible when photogrammetric surveys are properly planned and executed; and still others have changed their old ideas after a visit to a professional firm or organization engaged in photogrammetric engineering.

Fundamental to the preparation of reliable maps by photogrammetric methods is the understanding that all elements of mapping work must be accomplished through the use of highly precise instruments in the hands of thoroughly skilled and trained personnel. The term, "Photogrammetry", literally means "Measurements on photographs". The successful translation of measurements on photographs to produce reliable maps is the work of the Photogrammetrist. The major elements of the photogrammetric mapping process include: 1) The planning, procurement and processing of aerial photography, 2) The establishment of horizontal and vertical ground control, 3) The compilation of map details by stereo-photogrammetric techniques, and 4) The application of cartographic and drafting methods to prepare final maps in the format and symbolization required by the user of maps.

Let us briefly review each of the mapping elements:

1. AERIAL PHOTOGRAPHY

Aerial photographs are taken through the use of a precise, fully calibrated aerial camera. The Zeiss and Wild Cameras which are most frequently used have a high resolution, low distortion lens and provide photographs that are amazingly sharp and clear. Calibration marks affixed to the camera body provide a means for making precise checks of all elements of the photographic imagery. Aerial cameras are sent to the U. S. Bureau of Standards and/or the U. S. Geological Survey for full certification and determination of calibration data.

The aerial camera is a precision instrument. Before the advent of the currently used camera lens, the elements of lens distortion made it necessary to restrict photogrammetric measurements to the central portions of each photograph. This caution no longer applies; the aerial photograph taken with todays camera is virtually free of lens distortions. Images are recorded on high resolution emulsions which are placed upon various types of mylar base aerial films. This insures good imagery under different atmospheric and ground conditions and a stable base which is free of expansion and contraction of the film due to temperature and humidity changes.

The photogrammetric engineer designs the plan for the flight crew in order to meet the technical requirements of the final map to be prepared. This includes the determination of the flight altitude (a factor which establishes the scale of the photographs), the direction and location of the flight lines, the side and forward overlap between exposures, the aerial camera and film to be used and the conditions and time when the photographs are to be taken. The flight crew executes the flight plan which is usually shown on USGS quadrangle maps or the best available existing maps of the area to be mapped. The crew prepares a detailed flight report of their completed mission. The film is processed in the laboratory in accordance with the conditions reported by the flight crew and the requirements for the development of the film. Extreme care must be used in the processing and printing of the film. The photography is checked by the photogrammetrist for full compliance with his flight plan, and when necessary, reflights are ordered.

The resulting aerial photography provides a complete picture of the terrain and each image is a part of a mathematical geometric pattern. The photograph is a conical projection of the terrain. All terrain features regardless of their elevations are shown on a flat surface, that is the plane of the aerial negative. The plane of the photograph may be tilted with respect to sea level. These are the technical problems for the photogrammetrist to solve if he is to convert the vast information on the photographs to a true map which is an orthographic projection.

Aerial photographs are taken so that successive exposures in the line of flight overlap each other by approximately 55% - 65%. In the area of overlap, images will occur on at least two photographs, and these may be viewed, when properly oriented, to achieve a stereoscopic or third dimension effect. The area of overlap is called a "Stereo Model" and this becomes an essential part of photogrammetric mapping.

The basic geometry of a pair of aerial photographs is shown in Figure one (1), Page 4

2. FIELD CONTROL

The solution of the geometric problem of the aerial photograph requires the location and orientation of each photograph in space, that is, the recreation of the position of the camera at the time of each exposure. This may be accomplished by a purely mathematical (analytical) computation, or by mechanical-optical methods using a stereo plotting instrument. In theory, the orientation of two overlapping photographs is accomplished by determining their relationship to each other (interior orientation) and their positions and orientation with relation to the ground (exterior orientation). The Surveyor and the Photogrammetrist now work together in the planning and the obtaining of the necessary photo control. Since the photogrammetrist is solving problems in spatical geometry the old theorem, "three points determine a plane surface" still applies. Images visible on the aerial photography which can be found by the surveyor in the field are selected by the Photogrammetrist for horizontal and/or vertical control. Points in relatively flat areas such as fence corners, lone small bushes, visible marks on roads, intersections of sidewalks, poles, etc. are selected in areas which are accessible and which provide a geometric pattern for the solution of the orientation. Points in a straight line are not acceptable. In practice, four rather than three photo control points usually are chosen. Extreme care must be exercised by field survey personnel to identify, pin prick and describe the control points selected on the photographs. In effect the photos provide a medium of communication between the surveyor in the field and the photogrammetrist in the office. For large scale mapping projects, panels in the form of crosses usually are placed on the ground prior to the taking of the photographs. These panels serve as readily identifiable control images and greatly facilitate work and accuracy of the field surveyor.

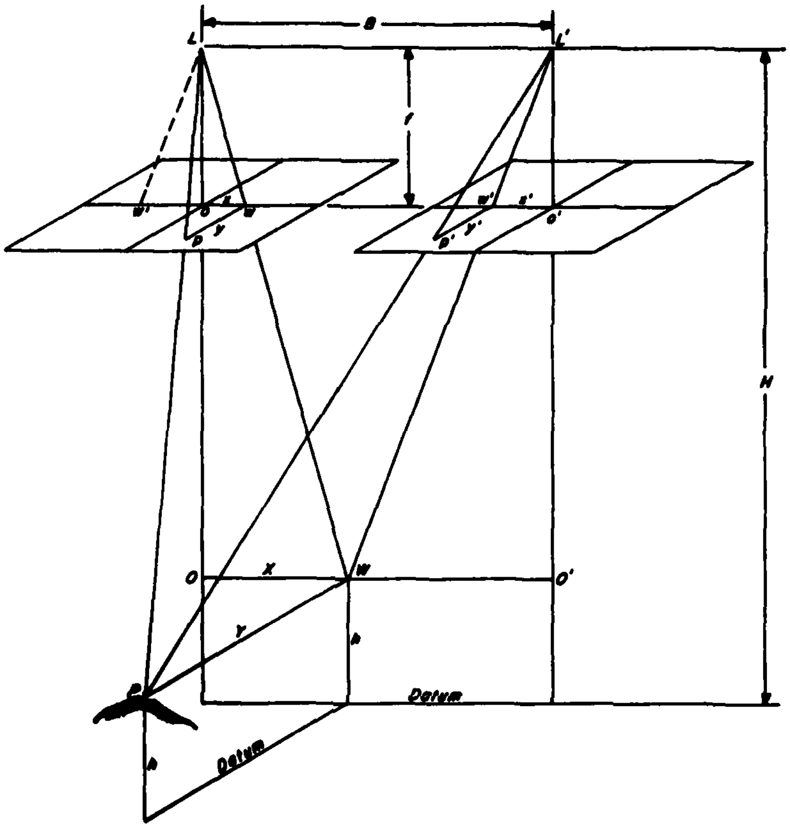


FIGURE 1

THE GEOMETRY OF A PAIR OF AERIAL PHOTOGRAPHS

f = Camera focal length
B = Air Base - The Distance between exposures
H = Flight altitude above Datum
h = Elevation of Point "P" above Datum
O and O' = The Principal Points of the Photographs
L and L' = Exposure Stations

Three and four vertical control points and at least two horizontal points are desired for each stereo model. In some areas it may be impossible to select and locate reliable control points. In these instances, the photogrammetrist can use his stereo plotting instrument to extend or "bridge" through one or more stereo models. The placement of the photo control points is important, and the accuracy of the ground surveys is vital to the final accuracy of the maps. Normally good Third Order Class I procedures and closures are used. The planning of the control should take into account future needs for horizontal and vertical control data in the mapping area, and points along the traverse and level routes should be suitably monumented and preserved.

For many projects control can be extended through an area by analytical aerial triangulation methods. When using an analytical solution, the aerial photographs provide the means of making measurements to apply mathematical formula to compute the orientation of a strip or block of aerial photographs and to calculate the position and elevation of photo points. The analytical solution permits an overall least squares adjustment of the control. The photogrammetric procedures require the picking and transferring of selected points on the photographs; the measurement of the photo coordinates of the points using a comparator; the computation of the spatial orientation of the individual photographs and a final adjustment of coordinates and elevations for photo identifiable points throughout the entire photographic coverage. For the best results, ground control points, both horizontal and vertical, must be established at predetermined locations to provide strong geometric data for the analytical computations. These important points should be panelled in the field in advance of the aerial photography. When properly planned and executed by experienced photogrammetrists, the analytical extension of control can provide highly accurate and reliable positions and elevations to be used in stereo photogrammetric mapping work.

3. PHOTOGRAMMETRIC MAP COMPILATION

Stereo photogrammetric plotting instruments are designed to fulfill three major functions; one, to enable the photogrammetrist to see stereoscopically, that is, the third dimension; two, to provide the means of making accurate measurements in X, Y, and Z; and three, to effect the plotting of photographic data in an orthographic projection, that is, changing from a conical projection (the photographs) to an orthographic projection (a map). The Plotting Instruments available today range from highly precise expensive and sophisticated instruments principally made in European countries, to less precise equipment, which however, when properly used, can produce highly reliable maps. The major differences in plotting instruments lie in the operating ratios of photo to plotting scales, their versatility in plotting and in the clarity of the imagery as viewed by the stereo operator in the mapping process. Many people remember the Multiplex Stereo Plotter which in the 1930's was the forerunner of the Kelsh Plotter (an American designed and manufactured instrument). The Kelsh Plotter and similar projection type instruments have been used extensively in American photogrammetric mapping. Within the last few years, the optical, direct-vision plotting instruments manufactured by Wild Heerburgg (Swiss), Kern (Swiss), Zeiss (West Germany) Santoni (Italy), Galileo (Italy), Zena (East Germany) and others have sold an increasing number of their instruments to American Photogrammetrists. Each Company produces instruments having different characteristics and operating ratios. While not offically categorized as first, second or third order plotters as can be done with surveying instruments, the stereo plotters do fall into a similar pattern of overall accuracy and universal use.

Following extensive investigations, our firm decided to buy the Wild A-10, Universal Plotting Instruments which seem to best fit our needs and requirements. Various firms and government agencies have selected other equipment and a wide variety of the European instruments are in use in this Country today. Automatic plotting instruments are in use in some military agencies and the Army at Fort Belvoir, (ERDL) has conducted extensive research and development of such equipment.

The plotting instrument is, of course, a most important part of photogrammetric mapping, however, it is the professional planning and use of the instrument under proper conditions of photo scale, reliable ground and/or analytical control, by thoroughly trained and qualified stereo photogrammetrists that produces the final maps. All operations in the mapping project must be designed to meet the needs and requirements of the map user, and limits of accuracy for each phase of the work must be established and supervised throughout the progress of the project. In the use of stereo plotting instruments, the operators must not exceed predetermined limits in the adjustment of the orientation of each stereo model. In our operations, we require a written Orientation Report for each stereo model. This provides a means of supervisory checking and a re-setting of the model, if necessary, at a later date.

A stereo plotter operator should have a mathematical concept of his responsibilities, keen well balanced eye sight (this does not preclude the use of glasses), a good knowledge of topography, map symbols and a strong enjoyment in the day-by-day creation of maps under his hand. To some people, the task of stereo plotting may be a boring and repetitious occupation however, the dedicated and proficient operator finds that his work is a constant challenge toward perfection and the thrill in developing and defining the details of Mother Nature.

Manuscript maps are compiled on stable base material, such as mylar, to maintain overall stability and accuracy. Control points are plotted on the manuscript usually by use of a precise coordinateograph. The orientation of the overlapping photographs is accomplished in the instrument by the optical mechanical means of establishing the tilts of the individual photographs, so that in stereo the control points, both horizontal and vertical can be read to their correct values. The geometric relationship between the two photographs is established and then the stereo-model (both photographs) is oriented to the ground control at the scale which has been selected for the plotting work.

After an acceptable orientation, the compilation of the map is accomplished by drawing, the planimetric details (roads, streams, etc) and then contours. The map information to be compiled and the contour interval which can be plotted is a function of the scale of the photography and the stereo plotting instrument used on the project. A commonly used term in American Photogrammetry is the "C" factor. This is the ratio of the flying height to the contour interval. For example, photographs flown at an altitude of 6000' (1" = 1000') used to map a 5' contour require a plotting instrument having a "C" factor of 1200 or better. Over the violent protests of the European manufacturers and Photogrammetrists, the American habit of rating various plotting instruments to a "C" factor presists. In my opinion, final map accuracy is achieved through the careful planning and supervision of all phases of the mapping process with due attention being given to the stereo plotter to be used.

The map manuscripts should be reviewed and checked. We call this a "Manuscript Edit". Large scale maps to be used for engineering design and the determination of earth quantities should be further reviewed and checked in the field for completeness and accuracy. National Map Accuracy Standards - "90% of all horizontal positions within a 1/40th of an inch at final map scale; and 90% of the contours within ½ the contour interval" are usually applied to maps whether the data is compiled by photogrammetric or ground survey methods.

4. FINAL MAP SHEET PREPARATION

Final drafting is accomplished to provide uniform size map sheets, standard map symbols, state and/or UTM grids, titles, credit notes, north arrow, scale bar and special data required by the map user. Final map sheets for engineering usage are drawn or scribed on mylar material. A skilled cartographer plans the final map sheets so that all features will be shown using prescribed or standard symbols, in a clear and readable manner. Lettering shoud not obscure important features and should be accomplished using lettering guides. Completed maps should comply with the specifications and requirements of the user.

A relatively new innovation in photogrammetric mapping is the Orthophoto Map. An orthophoto is prepared using special orthophoto plotters to transform the photographic positions on the original aerial negatives to their true or orthographic positions. The result is a fully corrected photograph on which true distances may be scaled. Distortions caused by scale changes, tilt of the photographs and topographic relief are removed in the orthophoto process. The preparation of an orthophoto is, of course, the exception to the rule, "A photograph is not a map." The methods used to prepare orthophotos are similar to those employed in regular photogrammetric mapping. Basically, high quality aerial photographs taken with precision type aerial cameras must be obtained. Horizontal and vertical ground or analytical control is needed to orient the overlapping photographs in an ortho mapping plotter. The photographs are viewed stereoscopically and the ortho plotting instrument provides the means to effect the transformation of the photographic images to an orthographic projection. With the completion of an orthophoto, it can be used as a base map for the subsequent plotting of contours consistant with the scale of the original photographs and the stereo-plotting instrument to be used. The contours, usually are drawn on an overlay to the orthophoto. The resulting contour overlay is scribed to produce uniform line weights and may be printed with the orthophoto to form a composite orthophoto map.

The Orthophoto map is a most effective means of presenting map information. The photographic base shows all features within the area of coverage, the contours depict the terrain and subsequent engineering designs can be super-imposed upon the orthophoto map. We foresee an increasing use of this type of mapping. Our K-320 Orthoscan instrument is used to provide orthophoto maps at a wide variety of scales and contour intervals, and our clients have been very pleased with their appearance, reliability and use in analyzing terrain and in the presentation of engineering data. One such client is the Philadelphia District of the Corps of Engineers.

Photogrammetric techniques are being used to obtain reliable information about physical objects and the environment through processes of recording, measuring and interpreting photographic images. The conventional application in the preparation of topographic and special purpose maps is but a part of this fascinating phase of engineering. Close range photogrammetry has been used to measure and map objects which are difficult to study in other ways. Projects such as the determination of the shape and deformation of an astronomic radio reflector, deformation in human eyes and teeth and other medical studies have been accomplished by photogrammetric methods. Special techniques are applied to provide thematic maps and resources surveys in the fields of agriculture, archaeology, engineering, forestry, geography, geology and others.

Thousands of papers and articles have and will be written to describe the uses of aerial photography in the inspection and solution of a wide variety of problems. The aerial photograph is a vital tool in Remote Sensing, but remember, the results which can be obtained are directly related to the technical skill, basic knowledge and the equipment used by professional people engaged in this work.

THE ROLE OF REMOTE SENSING IN PRACTICAL GEOTECHNICAL AND ENVIRONMENTAL APPLICATIONS - A CONSULTANT'S APPROACH

A.D. Beccasio
A.E. Redfield
Dames & Moore
Washington, D.C.

ABSTRACT

The problems associated with population and economic growth, land use, environmental impact, and resource depletion are creating an increasing awareness of the need for sound evaluation of land and natural resources. Information required to assist the consultant in this evaluation can be rapidly obtained from existing satellite and aircraft remote sensing data, including black and white, color, color infrared, and multiband photography, thermal infrared, and sidelooking airborne radar imagery.

Dames & Moore routinely utilizes remote sensing imagery in support of a variety of geotechnical and environmental project applications. Types, scales, and formats of imagery used depend on the size of the area under investigation and the level of spatial and spectral detail required. The remote sensing investigation is generally performed early in the project since this is an excellent means of obtaining timely and cost effective information on existing geologic, soils, hydrologic, and land use/land cover conditions of a particular area prior to detailed field investigations, including test borings and geophysics.

This paper will discuss the practical applications of remote sensing data with primary emphasis placed on the utilization of conventional image interpretation techniques for a variety of geotechnical and environmental evaluations. Typical Dames & Moore remote sensing project applications that will be highlighted include regional and local geologic and land use studies for major facilities siting and sanitary waste disposal sites; terrain analyses for trafficability and cross-country movement; resource inventories for national parks; photogeologic investigations of transmission line corridors; and wetland soils and drainage mapping for highway alignments in environmentally critical wetland areas. The capabilities and limitations of various types of remote sensing imagery will be summarized and recommendations offered with regard to the best types of remote sensing data currently available to the consultant for geotechnical and environmental project applications.

INTRODUCTION

The consultant who specializes in geotechnical and environmental investigations is generally faced with projects which require rapid turn-around times since decisions regarding a particular site's suitability for development must be made well in advance of site design and engineering. One of the most timely and cost effective methods for evaluating site suitability is to employ remote sensing imagery in support of specific geotechnical and environmental project applications. We normally perform the remote sensing investigation early in the project cycle since we have found this front-ended approach to be the best means of providing an overview of existing natural and cultural conditions of the project area. This, in turn, enables us to narrow down, or "focus-in," on those particular areas where more detailed investigative efforts should be concentrated.

Over the last four years, we have performed a variety of remote sensing investigations for government agencies and private industry. These investigations cover a broad spectrum of application areas, including major facility siting, solid waste disposal siting, terrain analyses and resource inventories, transmission line and highway route assessments, flood plain studies, coastal processes, environmental analyses, and mineral resources exploration. In many of these investigations, the interpretation of remote sensing imagery provided the primary source of information for determining the capabilities and limitations of a particular area for planned development.

Project areas typically range from thousands of square kilometers for regional studies to less than one kilometer for site specific investigations. We have used LANDSAT and Skylab imagery, and high, intermediate, and low altitude photography flown with a variety of cameras, including mapping, panoramic, and multiband cameras, and a variety of film types, including black and white, color, color infrared, and narrow band with selected filters. The major prerequisite in all instances, with the exception of LANDSAT, is to acquire aerial photography flown with 60 percent forward overlap for purposes of subsequent stereoscopic interpretation and analysis.

This paper will emphasize the use of conventional image interpretation techniques for performing a variety of geotechnical and environmental project investigations. The major objective will be to demonstrate how the consultant uses this important data source to assist him in defining pertinent characteristics relative to bedrock and surficial geology, geologic structure, surface drainage, engineering soils, land use, and land cover, as well as in planning field logistics and site access. Our discussion will be concerned primarily with highlighting the results of some recently completed investigations dealing with major facilities siting, solid waste disposal siting, terrain analyses for military operations, resource inventories for national park planning, and corridor studies for transmission line and highway route assessments. We will present specific case histories, stressing where appropriate, the "coordinated approach" to remote sensing. This approach enables the interpreter to systematically focus-in on specific areas of interest, beginning with satellite imagery, progressing to more site specific aircraft photography, and ending with detailed field investigations, such as test borings and geophysics.

The important factor to bear in mind throughout this presentation is that we use remote sensing principally to fill basic gaps in existing data sources and to identify key engineering characteristics and potential problem areas not readily shown on traditional geologic and soils maps. Conditions such as the occurrence and distribution of bedrock outcrop, faulting and jointing, mass wasting, severe erosion and gullying, and karst terrain, to mention a few, are all vital to the geotechnical and environmental consultant because they have a decided influence on engineering parameters associated with slope stability, ease of excavation, foundation stability, and ground water potential.

APPROACH TO REMOTE SENSING INVESTIGATIONS

We normally perform the remote sensing investigation early in the project cycle. As shown in Figure 1, the first step in the process involves project definition, including the type of facility or structure planned and the size of the area to be studied. The size of the project area is an important consideration, because this parameter dictates the types and scales of imagery required. For regional siting investigations, LANDSAT, Skylab, or other types of small scale imagery are used for purposes of geologic reconnaissance, including the correlation of key structural trends and patterns. This imagery is acquired through the U.S. Geological Survey EROS Data Center as well as from private sources, depending upon the timeliness and availability of area coverage. Site specific investigations generally require photographic scales of 1:20,000 or larger for purposes of mapping the detailed natural and cultural features of the area. This photography is obtained from government sources such as the U.S. Geological Survey, the U.S. Agricultural Stabilization and Conservation Service, and state highway departments, and from private flying services. In certain situations, we recommend that aerial photography be specifically flown for a project in order to obtain the most recent coverage available, particularly where updated land use and land cover mapping, cartographic control, and revised plan and profile maps are required. During this presentation, those projects where we have flown aerial photography specifically for purposes of the job will be identified.

It is important to note that we also acquire available reports and maps of the region of interest early in the project cycle. These data are used during the image interpretation phase to assist in the evaluation of the area. The objective of our interpretation is not to duplicate information, but to use the remote sensing imagery to fill gaps in the existing data base, with primary emphasis on identifying potential problem areas and areas which require more detailed investigation, either by lower altitude, site specific photographic coverage, or by field investigations. As shown in Figure 1, the primary output product of the remote sensing interpretation phase is the compilation map, which summarizes existing regional and/or site specific conditions in the project area. This map provides the major information source for use in subsequent field investigations. During the course of a project, additional correlations or refinements are made on the interpreted data as updated field information is received. This coordinated approach, in turn, enables us to make maximum use of all data sources prior to formulating specific recommendations regarding site suitability.

SELECTED CASE HISTORIES

The remainder of this paper will summarize some of the ways in which we have used remote sensing imagery to assist us in operational geotechnical and environmental project applications.

Major Facility Siting Studies

Typical projects in this category include siting studies for nuclear and fossil fuel power plants, oil and gas processing, manufacturing, and storage facilities, and associated transportation systems. Project areas normally range in size from regional siting studies covering thousands of square miles to site specific evaluations of 5 square miles or less.

Remote sensing investigations for major facility siting studies involve the coordinated approach, incorporating LANDSAT imagery with high altitude black and white or color infrared stereoscopic photography, and ultimately, with low altitude black and white stereoscopic photography. In certain situations, the LANDSAT imagery may be by-passed in favor of a more detailed interpretation of site specific, larger-scale photography.

LANDSAT imagery, particularly bands 5 and 7, is used primarily for interpreting lineaments and fold structures and establishing relationships with regard to regional tectonics and structural grain of the project area. Aircraft photography of potential site areas and high priority candidate sites is used for more detailed evaluations, including the interpretation of geologic hazards such as faulting, landslides, or cavernous collapse, and the identification of key areas for subsequent field investigation. We also use the imagery for certain aspects of environmental and ecological mapping, such as assessments of existing land use and land cover, vegetation delineations, and house counts for determining recent population growth in the site vicinity.

The coordinated approach to remote sensing was applied to the siting of a major facility in the Hagerstown Valley of Maryland and portions of adjacent Pennsylvania and West Virginia. Existing geologic mapping in this region is highly fragmented with the exception of 1:250,000-scale statewide coverage. On the basis of the LANDSAT interpretation, supplemented by pertinent socioeconomic considerations such as population density and property acquisition limitations, a potential site was selected. Examination of the 1:72,000-scale U.S. Geological Survey photography indicated that a major portion of the potential site was characterized by karst terrain, a condition reflected on the photography by highly mottled tonal patterns and the absence of surface drainage. Specially flown, 1:12,000-scale photography covering the area showed the extremely karstose nature of the candidate site with remarkable clarity; numerous sinkholes and linear west-northwest trending solution valleys suggested that subsurface bedrock conditions were highly variable.

The results of the remote sensing interpretation were compiled onto 1:24,000-scale U.S. Geological Survey topographic maps, which were used by the field team during their detailed site evaluations. Locations for shallow seismic refraction survey lines were also recommended based on the interpretation. Subsequent field investigations revealed the highly fractured nature of the limestone and numerous sinkholes at the surface. An east-west seismic refraction line, across an area of well-defined lineament traces resulted in anomalous seismic velocity profiles which correlated remarkably with photointerpreted lineaments and bedrock features.

As a result of the coordinated remote sensor-field-geophysical approach described above, we were able to conclude within a 30-day period that geologic conditions at this site would preclude the development of a major facility without recourse to extensive and costly grouting measures to mitigate the effects of karst. The site area was excluded from any further consideration for planned development.

Nuclear Power Plant Siting Studies

The general NRC policy regarding nuclear power plant siting requires that each applicant for a construction permit investigate all seismic and geologic factors that may affect the design and operation of the proposed facility. This regulation requires that any faults greater than 1000 feet long within 5 miles of a site must be reasonably investigated as to whether they are capable faults. A capable fault is defined as one in which movement has occurred within the last 35,000 years, or multiple movements have occurred within the last 500,000 years.

The value of LANDSAT imagery as a reconnaissance tool for uncovering regional lineaments and previously unmapped faults is well documented and will not be discussed here. In addition to LANDSAT, we routinely use small scale aerial photography in defining the surface trace of previously undetected fault structures. As an example, the existence of a structure in the Virginia Coastal Plain, some 40 miles south of Washington, D.C., had escaped detection until it was discovered in the course of detailed field mapping by the U.S. Geological Survey in the mid-1970's. The proximity of the fault zone to a proposed nuclear power plant site made it apparent that the new-found features deserved serious attention in terms of potential seismic consequences relative to the design and operation of the proposed facility.

As a result, Dames & Moore was given the responsibility to investigate the potential seismic and engineering significance of this fault zone. A cursory examination of the 1:72,000-scale aerial photography over the area where the fault structures were reported clearly showed the existence of well-defined topographic and tonal alignments identifying the surface traces of the fault zone. Once the location and extent of the fault structures were determined, the delineation was transferred onto a 1:24,000-scale topographic map of the area.

Exploration sites for field trenching were then selected on the basis of the interpretation of the air photos. A log of one of the trenches, cut perpendicular to the fault zone, revealed the presence of numerous offsets including the major fault structure, which displaces the excavated sediments at an angle of 52 degrees. Subsequent detailed analyses of the sediments displaced by this fault indicated that no discernible recent movement has occurred along this structure, and it was concluded therefore, that neither this fault nor any of the other faults within the zone is capable according to NRC criteria.

Solid Waste Disposal Siting Studies

Remote sensing techniques are employed to assist us in locating potential solid waste disposal sites as well as in determining potential impacts of waste disposal sites on ground water conditions. In this regard, remote sensing imagery ranging from LANDSAT to low altitude aircraft photography are interpreted for purposes of regional and site specific geologic and soils mapping, fracture and lineament studies to define potential zones of high permeability, and mapping baseline conditions for land use and land cover assessments.

This case history will briefly describe a sanitary landfill siting study in nearby Montgomery County, Maryland, an area which has been extensively mapped from the standpoint of geology and soils. These maps, however, do not show the type of information required for the siting of a sanitary landfill, such as shallow bedrock, wet soils, and the presence of extensive fractures which could be indicative of zones of higher subsurface permeability.

As a result, prior to undertaking field reconnaissance studies, we performed a cursory evaluation of Skylab S-190B color photography and small scale (1:72,000) aerial photography for purposes of identifying areas within the county which should be excluded from further consideration due to the presence of shallow bedrock and extensive fracturing. The results of the interpretation, in the form of a lineament map of Montgomery County, had a direct bearing on the ultimate selection of candidate site areas for detailed exploration and ground water testing.

The subsequent detailed remote sensing investigation of the candidate site areas involved the interpretation of site specific 1:6000-scale black and white and color infrared stereoscopic photography flown specifically for the project. Using this imagery we were able to define local conditions of high soil moisture, bedrock fracturing, and the presence of seeps and springs, all important conditions to the siting of a sanitary landfill. This data, compiled onto a series of 1:1200-scale topographic maps, provided the primary input to the field investigation team.

Military Terrain Analyses

We have performed a variety of terrain analysis studies for selected military reservations under contract to the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia. These studies represent compendiums of available data on the pertinent natural and manmade features of the particular site area and are used in military planning.

A representative military terrain analysis case history concerned the Fort Carson reservation in south-central Colorado. Although this portion of the Front Range has been mapped in great detail, specific portions of the reservation were not extensively mapped due partially to remoteness and partially to restricted areas within the reservation, where entry is dangerous due to the presence of live shells and related undetonated ordnance. In such cases, we use available military air photos in defining key characteristics of terrain, particularly as these relate to surface drainage, engineering soils, engineering geology, vegetative cover, and cross-country movement. Prime consideration, of course, is directed toward assessing the suitability of the terrain for tactical military operations, such as trafficability and cover and concealment. An example where remote sensing greatly assisted us was in the use of selected panoramic frames to identify landslides and escarpments on the Fort Carson reservation. These conditions, which were not readily identified in available data sources, were of great importance in evaluating the overall capabilities of the reservation for the maneuverability of troops and military vehicles. The results of our interpretation were subsequently transferred to the appropriate engineering geology and cross-country movement maps of the Fort Carson reservation. These maps, in association with the other maps in a military terrain analysis, will assist military planners and decision-makers in assessing the capabilities of the reservation for future troop stationing and training requirements.

Resource Inventories

It has long been recognized that a prime requisite for better management, planning, and use of land in national parks is to compile relevant information on the natural and cultural features of these areas. A resource inventory typically comprises the collection, analysis, and mapping of baseline data on topography, geology, engineering soils, surface drainage, vegetation, and land use as well as related data on historic significance and archaeology. In assembling the relevant information on existing natural and cultural features, the majority of the data is acquired from existing reports and maps of the site area. There are instances, however, when existing data do not give us a complete picture of site conditions. One such case was in the inventory of resource variables for the Manassas National Battlefield Park, some 30 miles west of Washington, D.C. Although the area was well mapped, we did not have timely information on existing vegetative cover and land use. In addition, information as to local areas of gullying, high soil moisture, and shallow rock was spotty. Information of this type is critical to park planners for purposes of locating paths and trails, picnic areas, and structures requiring excavation. For this study, we flew black and white, color, and color infrared spot photography over the park area in order to better define the capabilities and limitations of the site for future development and expansion. This photography, in association with 1:24,000-scale stereoscopic aerial photography flown in 1977 and 1978, provided us with a wealth of data on engineering soils, vegetation, and land use. The black and white spot photography provided a major source of information for updating and revising topographic base map cultural features as well as existing land use/land cover conditions. The color infrared photography provided an extensive amount of information on vegetation types and distribution. In addition, we found the color infrared photography to be particularly useful for interpreting local areas of gullying, bare soil, high soil moisture, and exposed rock. The resulting interpretations, transferred to a series of thematic map overlays, provided a timely baseline from which the capabilities and limitations of the Manassas National Battlefield could be fully assessed by park managers and planners.

Transmission Line Corridor Studies

Remote sensing interpretations provide information on existing natural and land use conditions that can be anticipated along proposed transmission line routes, which can extend over hundreds of line miles. This reconnaissance technique enables us to quickly obtain information about large and often inaccessible areas, identifying pertinent geologic conditions and potential foundation problems. It assists in the planning of the field investigation program and in the interpretation and correlation of data obtained from the test borings. In addition, since major portions of transmission line routes often cross wide, inaccessible stretches of mountainous, heavily forested, or swampy terrain, knowledge of existing roads is useful for determining accessibility by men and drilling equipment.

We have, to date, employed photointerpretation techniques in the foundation investigations of a variety of transmission line routes; some lines cross flat, coastal plain terrain; others cross relatively high relief, mountainous terrain. A representative transmission line investigation, which we recently completed in the Coastal Plain of southeastern Virginia, clearly demonstrates the use of the remote sensing technique in an operational project application. This project involved the stereoscopic interpretation of large scale (1:12,000) aerial photography for the purpose of defining existing geologic conditions; the preparation of a comprehensive photogeologic strip map of anticipated conditions along the route; the pinpointing of test boring locations based on the photo analysis; and the direction of subsequent drilling in the field, including logging and sampling of the subsurface profile.

We have found the remote sensing technique to be superior to conventional field investigations alone. Conventional field investigations of transmission line routes generally locate test borings at average spacings of 2000 feet along the extent of the line. Consequently, more holes are drilled than are generally required, resulting in a costly and time consuming field exploration program. In addition, the boring logs do not give an accurate portrayal with regard to variations of lateral graduations in the surface section. This, in turn, makes the correlation of boring logs from hole to hole exceedingly difficult. The use of photointerpretation and the analysis of the photogeologic maps enables us to concentrate our field activities along specific segments of the line where potential problems could be encountered. This pinpointing of target areas results in a 50 percent reduction of test borings that would otherwise be required using conventional field investigative techniques alone and is very cost effective.

CONCLUSIONS

The practical utilization of remote sensing has been demonstrated by means of selected case histories dealing with specific geotechnical and environmental project applications. In all instances, we have used remote sensing early in the project cycle to provide basic information to the project team prior to costly field reconnaissance and exploration activities. The approach is rapid and cost effective as illustrated by some of our case histories, all of which were completed within one-month's time including interpretation of the imagery and the preparation of a compilation map defining existing site conditions and problem areas. Subsequent field reconnaissance activities, supplemented by site specific exploration techniques such as test borings, excavation trenches, and geophysics, confirmed the interpretive findings and assisted in the detailed engineering evaluation of site conditions. The option to revise and correlate interpretive results, based on pertinent field findings, is of paramount importance to the success of the project.

In terms of the capabilities of various types of remote sensing imagery, LANDSAT bands 5 and 7, acquired during the late fall to early spring periods, are best suited for assessing regional geologic structure, a key prerequisite to major facility siting. Although it was not discussed in this paper, the repetitive coverage provided by LANDSAT is optimum for monitoring dynamic, time-variant phenomena such as coastal processes, wetlands encroachment, urban expansion, and status of vegetative cover, to mention a few. This capability is a valuable asset which cannot be overlooked in environmental applications. Skylab Earth Resources Experiment Package (EREP) photography, due to fragmented and inconsistent coverage patterns, is generally not an important data source, except in particular instances where the area of interest is within the coverage swath of its sensors. In specific cases where Skylab imagery was used, the spatial resolution and the capability for stereoscopic viewing greatly assisted in enhancing the interpretation of regional geologic structure and surface drainage.

Small scale (1:60,000 to 1:120,000) black and white and color infrared photographs are extremely useful for regional geologic structure and land use/land cover mapping. Detailed information can be extracted from this type of imagery, and there is the added capability that each frame covers a large ground area, which results in a small number of photographs to be interpreted. For all site-specific geotechnical and environmental applications, photographic scales between 1:10,000 and 1:20,000 are best for interpretive detail and cost effectiveness. Scales larger than 1:10,000 are generally not recommended, except in areas of very limited size, due to obvious cost constraints.

Terrain and drainage mapping can best be accomplished by stereoscopic viewing, a technique which greatly assists in the interpretation of subtle landforms and geologic structure. The importance of stereoscopic viewing cannot be overstressed. These features are, in turn, best interpreted on aerial photographs acquired during the late fall-early spring time periods. Soil moisture and wetlands conditions are best interpreted on early spring, color infrared photography at scales of 1:20,000 or larger.

In summary, the consultant is product-oriented, placing major emphasis on practical results and solutions to problems. Remote sensing is a timely and cost effective means to this end.

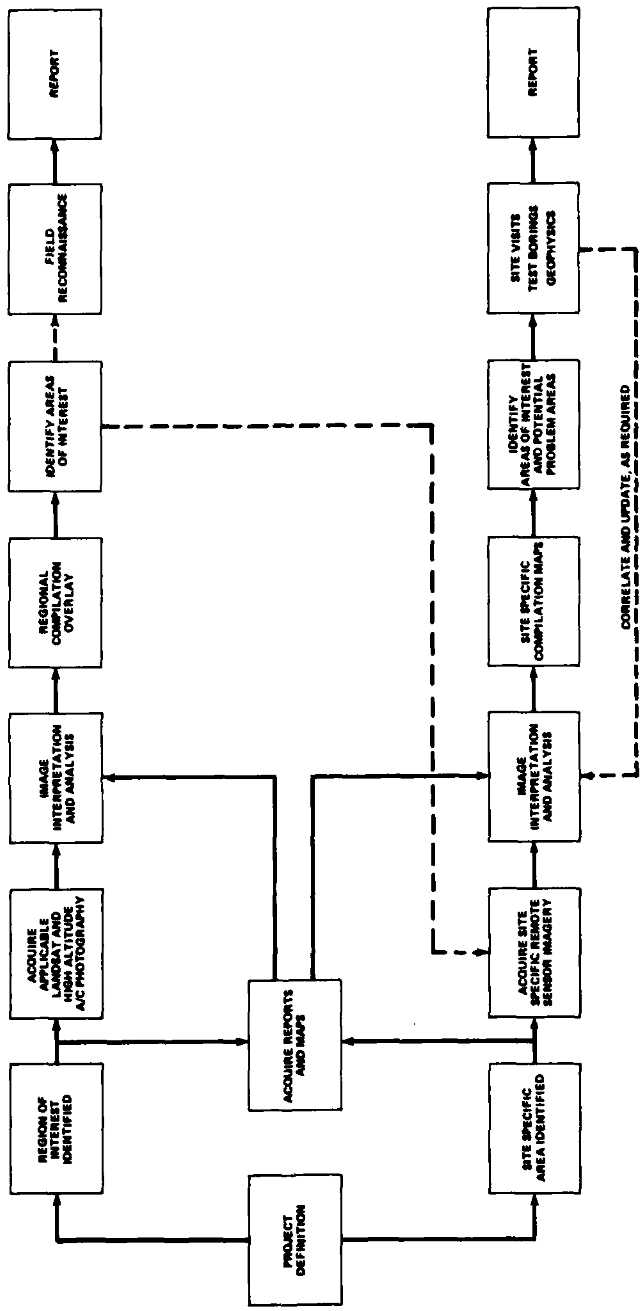


FIGURE 1
TYPICAL REMOTE SENSING FUNCTIONAL FLOW

CORPS OF ENGINEERS REMOTE SENSING APPLICATIONS AND IMAGE PROCESSING TECHNIQUES*

by

CHARLES A. HARLOW
Department of Electrical Engineering
Louisiana State University

and

J. M. Hill
Division of Engineering Research
Louisiana State University
Baton Rouge, LA 70803

ABSTRACT

Image Processing techniques can be conveniently discussed in the categories of calibration, preprocessing, enhancement, segmentation, change detection primitive operators and geographic data processing. The techniques in general are not limited to Corps of Engineers' problems or for that matter to remote sensing applications, but also are used in medical image analysis and robatics. It is important to realize that some techniques can in principle be directed towards new applications while others might require research and an extensive effort to implement. Some typical problems of interest might be: water location, changes of water boundaries with time, location of traffic and fixed objects in waterways and determination of soil types. Some problems such as the location of large water bodies may be straightforward. The other problems may not be so simple. Satellite data may be helpful, but many problems with high resolution requirements may use aerial photography. Ground truth information available from control points or maps will also need to be used in the analysis. A satisfactory system might be an interactive system where an investigator invokes available functions such as image enhancement, rotations, magnifications and ground truth overlayed on the imagery. If one is interested in an automated system for analyzing imagery, the situation may be complex. Image segmentation methods for automatically locating objects or features in an image in general require skill to use correctly. In analyzing complex scenes it may be very difficult to build automated analysis systems. One has available a number of analysis techniques to use. These include edge, texture operators as well as the various approaches to segmentation such as clustering or region growing techniques.

*Supported in part by AFOSR Contract F49620-79-C-0042

I. INTRODUCTION

Image analysis basically refers to the process of developing software and systems to analyze scenes. Classically the scenes have been produced by having a T.V. camera scan a scene in a room. This gave rise to studies in what might be considered robotics. A typical goal would be to identify objects on a table so that a manupilater device could STACK or otherwise arrange the objects. Other early typical examples utilized microscopic images for cell studies or the analysis medical radiographs to have the computer diagnose heart disease. These are just a few of an enormous number of examples that could be cited. In all cases a scene is scanned and a gray level array is produced that must be analyzed. Color is not often used, but they are examples involving natural landscapes where this type of analysis has been performed. Since image analysis involved the solution of particular problems, these applications have to a certain extent controlled the development of existing analysis techniques.

One basic tenet that was discovered early was that the absolute gray level of a pixel (picture element) is of little value. The typical scenes considered, a camera mounted in a robot rover, for example, acquires images under widely varying orientations and lighting conditions. Hence, the pixel can have tremendous variations in gray levels. Another example would be scanning film products. The gray level for a given pixel is a function of the film development process and the scanner settings for the device that produces the result gray level, hence varying the parameters, the pixel gray level can be made to assume almost any value.

Another basic tenet is that gestalt information must be used in the analysis. Imagine one is attempting to locate the position of, say, a tank. As previously mentioned, there will be wide variations when one considers pixels or other local targets but a tank will always be composed of turrets, tracks and guns in a certain arrangement. The global information remains constant and is used by humans in their visual recognition tasks. Let us now consider remote sensing applications.

Remote sensing applications in image processing have similarities to traditional image analysis problems, but there are also some differences. In remote sensing applications, the scenes to be analyzed are always real rather than artificial. An artificial scene might consist of a table with manmade objects of a known geometry on it. Manmade objects such as reservoirs or roads do appear in remotely sensed data but they are embedded in a natural environment (i.e., forests, marshes, agricultural fields). Natural scenes have been traditionally difficult to analyze, because the line and gray shade patterns in such scenes are irregular and nonhomogeous. Remote sensing data are acquired through use of sensors mounted on an airplane or satellite. The difference between sensors mounted on these type of platforms are that:

a) Aircraft data are generally of a higher resolution
b) Navigational and georeferencing information are generally more readily available when using satellite systems

From an image analysis point of view the data with a courser resolution will have less details present which at times simplifies the analysis.

The sensors themselves used for acquiring remotely sensed data are quite varied (i.e., camera, multispectral scanner, radar). This is apparently because of a strong desire to match the sensor to the specific spectral response of a desired feature, to get increased resolution, or to get continous coverage in all types of weather. Aircraft mounted cameras and multispectral scanners (MSS) are typified by the Daedalus MSS system, laser range finding systems, and SAR systems. NASA, NOAA and DMA, satellite systems also carry a wide variety of MSS scanners, altitude sensors, radar systems and atmospheric sensors. Clearly much emphasis has been placed upon sensor development. As a consequence for a given scene one will have available a number of spectral bands available for analysis. A major emphasis (need) exists in the detailed analysis of the response of specific surface features in certain spectral bands, examples of which are sensing land and water surface temperatures and determining land cover. Other examples are analyzing surface responses to radar signals including both magnitude and phase (vertical or horizontal polarization). This tends to place an emphasis on analyzing the response at a point, or pixel, to locate features of interest. As such, the analysis tends to resemble traditional signal analysis and is not very closely related to traditional methods of image analysis. At times color imagery has been studied which is composed of 3 primary color bands, but this has largely been the exception to the rule. In medical applications where examinations at times include ultrasound, thermography and computerized timeography one will increasingly have different bands of data to process, but it suffices to say that a major new factor in the analysis of remotely acquired data relative to scene analysis is the large number of different spectral bands. Image processing techniques to systematically process these MSS data remain to be developed. Most image processing algorithms have tended to heavily utilize the spatial information in processing data, i.e., if (x,y) is a point on pixel $g(x,y)$, the gray level, is processed together with $g(x_1, y_1)$ where (x_1, y_1) is in a neighborhood C of (x,y), $C_{x,y}$. The quantity $g(x,y)$ alone is recognized as not very indicative of features. For example, if point (x,y) is in a forest it is likely its neighboring pixel is also in forest area. These mutually reinforcing concepts can increase the probability of correctly labeling or classifying the land use. The MSS data necessitates extending the analysis methods to $g(x,y, \lambda)$ where λ is wavelength (In the remainder of this section we will give some common image processing and remote sensing terms so that later discussions will be facilitated).

The image processing function is envisioned as shown in Figure 1. The investigator has available a number of input media and interactive

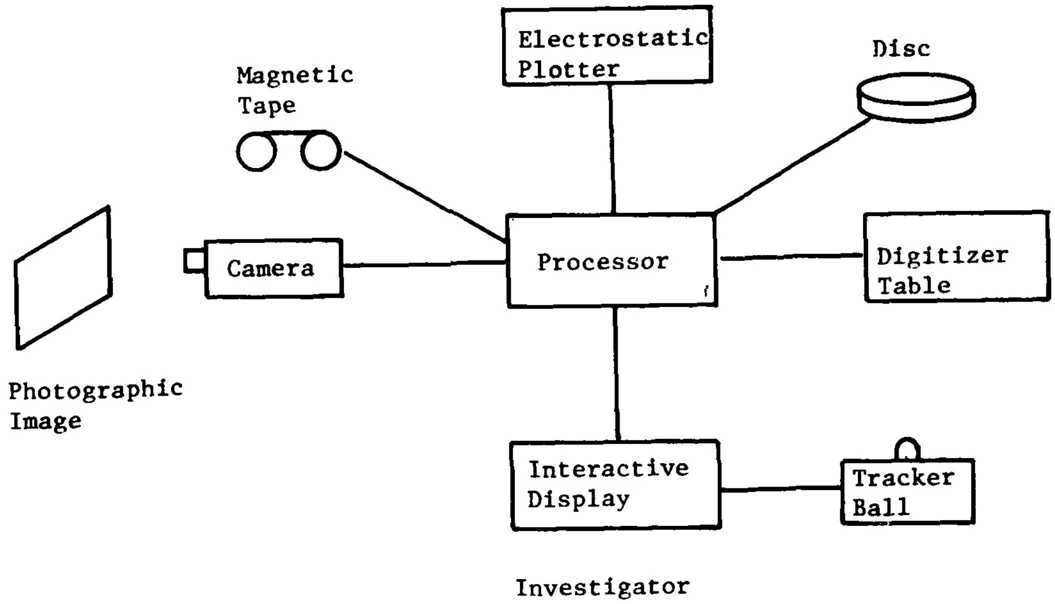


Figure 1. Image Analysis System

devices. He also has available an extensive array of software to aid in the analysis of the imagery. Much of this software is in the form of support software to allow the investigator to interrogate the imagery. Examples would be image rotation and enlargement or interactively designating an area of the image (the selection of known training fields). Other software supports the actual analysis of the imagery, or parts of the imagery. The analysis function can be viewed as shown in Figure 2.

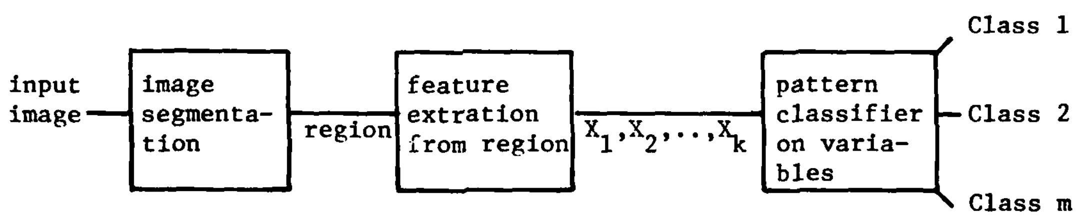


Figure 2. Image Analysis Function

The segmentation (classification) could be done automatically or interactively, possible after extensive image manipulation. After a region is determined then analysis procedures are invoked and variables characterizing the region are extracted. An example of an analysis technique would be histogram or texture analysis in which texture variables are extracted from the region. Another example would be the use of change detection algorithms which could be used to detect changes in images from day to day, from season to season, or year to year. The algorithms relevant to remote sensing can be divided into the following areas to facilitate their discussion.

Preprocessing and Enhancement

Often processing is required to modify the gray level distributions of the data in order to improve subsequent viewing by investigators. Examples are contrast transformations, histogram modification algorithms, as well as numerous transform based filtering methods. They are of value when the signal/noise is of some known form.

Pseudo Color Display

Often the data obtained from remote sensors has a larger dynamic range than can be displayed information. Techniques for displaying the information are often heuristic in nature.

Calibration of Sensor Output

Often calibration is required to correct known distortions of the sensor output, correct the data using internal calibration data, and reformat the data.

Input/Output Support Software

Data may arrive in different formats. Software is required to read different formats and convert into the format used by the system. Also it may be required to output image data in a variety of formats and engineering units appropriate for each image class studied.

Geometric Correction and Geographic Registration

The earth as seen in satellite scanner generated data is distorted from the true geometry of the earth for any standard map projection. It is required to remove these distortions and to overlay such data onto a standard map projection.

Image Manipulation

Often it is desired to view the imagery in different orientations and magnification in order to make surface features more apparent. It is also useful to overlay different remotely sensed data and known surface features such as land surface topography. This will require the ability to generate 3-D surface descriptions, register data and manipulate data bases.

Interactive Image Display and Measurement

Analysis of remotely sensed imagery requires substantial interactive capability because of the complexity of the images and the wide variety of features to be analyzed. For this reason software and hardware is required which enables an investigator to select areas or points of an image and make measurements from these areas or else store the areas for future analysis.

Geographic Data Base Management

Geographic data base management refers to the process of storing, retrieving and manipulating all forms of sensor data and surface truth data in an efficient convenient manner. Obviously desirable would be the ability to overlay different images, maps and ground truth in order to correlate surface features. A powerful data base facility is very useful and is often not available in image processing systems.

Classification Algorithms

Classification algorithms are the decision rules that actually perform the classification in the image data and in this regard is envisioned as an image processing function as shown in Figure 2. An obvious example of the classifier would be the Bayes Decision Rule. The image segmentation could be done interactively or automatically. Pattern classification is itself a complex statistical process. There are a large number of different techniques that have been used in the past. In addition, syntactic and tree structured decision rules are currently being developed and they often demonstrate superior results. Also involved in pattern classification is experimental design. This involves significant statistical questions about the validity of the results, for example, the number of training samples, the number of measurements extracted and percentage confidence in the result are all related and must be part of the design of any experiment.

Automatic Image Segmentation

Algorithms for automatic segmentation perform the task of automatically locating the objects, or targets, of interest in the scene. In general this is one of the most difficult tasks in image processing. Since remotely sensed images are complex, it is likely that fully automatic segmentation algorithms will be difficult to achieve and therefore some level of human interaction will be required. Nevertheless automatic segmentation algorithms are of significance when large amounts of data must be processed and available displays will not display the complete range of sensor data.

Texture Analysis

Texture analysis is closely related to image segmentation in that most segmentation algorithms would likely use texture operators. Texture is here listed in a separate category because texture is such an important operator in remote sensing operations. A texture pattern can be intuitively described as a property characterized by a distribution of gray levels over a region in the image. Virtually every pattern that occurs in remotely sensed data is of this type. Examples are forested, agricultural, clear-cut areas and wave patterns in the ocean. The analysis of texture is difficult, but is becoming better understood using statistical and structural models.

Change Detection and Time Lapse

Change detection refers to the process of locating areas in an image that have changed from one image to another. This is important because one is often only interested in the changes that occur in scenes. Examples are changes in the coastline, current patterns and navigational hazards. Time lapse is included because one might desire to produce a sequence of time lapse images depicting the changes that occur.

II. APPLICATIONS

The purpose of this section is to discuss Corps of Engineers problem and application areas that have relevance to remote sensing. An attempt will also be made to relate the applications to image processing functions and to describe which areas require additional research and those areas which are relatively straightforward development tasks.

Since the applications are so varied, it is difficult to devise categories sufficient to decsribe the needed analysis. We will, however, use the previously described terms in order to provide structure to the discussion.

Let's briefly describe the COE application terms: [1]

1. Vegetation--In examination of vegetation coverage one must categorize the type of vegetation. This includes aquatic weeds, kelp, forests, wetlands, etc. This has pertinence to such project areas as image assessments, environmental impact, and economic assessments, trafficability, camouflage studies, and target recognition.

2. Land-Use (Cover)--This can include discrimination of such varied parameters as urban, residential and recreational areas.

3. Change/Growth Trends--Involving changes in anything from land-use changes in marsh or levied areas, to urban growth, to erosion along rivers and coastlines.

4. Geology/Terrain--Determination of soil types and topography for such projects involving dam siting, reservoir siting, construction siting, environmental impact assessments, and drainage basin delineations.

5. Reservoir Mapping and Operations--Which often involves identifying water bodies and the quantity and quality of water within each.

6. Habitat Dilineation--Involving a multitude of parameters including vegetation, terrain, geology, water supply.

7. Relocation and Corridor Planning--This involves the selection of ecologically and economically sound alternative sites or routes.

8. Archaelogical Sitings--Historical sites must be located, mapped, and excavated before an area is flooded.

9. Trafficability--Areas must be completely surveyed as in respect to vegetation, topography, soils, etc. in order to predict the speed of mobile units across such an area.

10. Pollution Sources--Nonpoint (i.e. agricultural fields, pastures) and point sources (i.e. pipes and smoke stacks) of pollution must be located and quantified.

11. Erosion--Detection and sometimes prediction of changes along land-water boundaries and in areas away from water bodies, but affected by rain (runoff).

12. Water Quality--Involves monitoring land-use (cover) in drainage basins around or along water bodies, and the monitoring of biological, chemical, and physical constituents of the water and associated current patterns (dynamics).

13. Navigation--Usually involving the detection and adding of new structures (hazards) to nautical charts; this includes changes in underwater channels, shipwrecks, moved buoys, and changes in coastlines, islands, rivers, and canals.

14. Environmental Impact Assessments--Generally, depending on the specific project, nearly all the above parameters are included at one time or another; assessments can be predictive or after the fact.

15. Regulatory Functions--Monitoring usually involves detection of changes such as permitted activities and vegetation damage.

16. Litigation Preparation--These types of projects involve the gathering of data which must be scientifically sound and admissable as evidence in court; a multitude of areas can be included all the way from dredge disposal sites to flooded towns or cities.

Let us now briefly examine the action terms or processing terms. Some of the terms have been derived from photointerpretation while others are standard image processing terms.

1. Shape--refers to the shape of an object.

2. Size--refers to the size of an object.

3. Tone--a general term which means that a maximum and hopefully unique spectral response is known which directly relates to the feature.

4. Pattern--this is a photointerpretation term which reflects the interspersion of certain man-made and natural features. To determine the existence of such features would require location of these features. The overall discrimination is then made in a gestalt fashion.

5. Context--this means the feature can only be identified by first determining its location and proximity to other features. In image processing terms this is often designated as identification within context.

6. Texture--standard image analysis term which usually denotes a distribution of color or gray shades over a region.

7. Change Detection--image analysis term referring to detecting changes that occur in regions.

8. Segmentation--image analysis term that means locating an object in a scene. This is often called target identification in remote sensing applications.

9. Shadow--this is a photointerpretation term which indicates that one desires to obtain 3-D information. Shadows indicate this information as do stereo images.

10. Geographic data processing--this term refers to the facts that are needed to process, reformat and display scene and point spatial data. This includes overlaying and registering spatial data derived remote sensing, maps, and other sources.

11. Modeling--this refers to programs which take input spatial data and predict, or simulate, the results of some environment process, for example erosion, flood plain delineating and associated damage assessment.

Consider, as an example problem, the determination of water quality. An issue related to water quality is determining the distribution of water bodies of different temperatures. In this regard one may be interested in; a) locating surface thermal features (patterns) and b) measuring the absolute surface temperature of water.

In order to accomplish these tasks one must first select the appropriate remote sensor and analysis procedure. Issues in sensor selection are frequency, spatial and spectral resolution. For instance, Landsat data provides a multispectral, moderately course resolution (1.1 acres), synoptic historical data base of nearly the entire United States since 1972. Landsat systems have, however, not had a thermal sensor until the launch of Landsat 3 in 1978 which has a resolution which is approximately one third of the other four spectral channels. Camera systems, can be used to monitor more detailed features as in the case of counting individual targets (i.e., boats, ducks, dredging and disposal operations), but film-camera combinations cannot be used to detect temperature differences. If one wanted to monitor the temperature of a target, an aircraft or satellite borne thermal sensor would be utilized to acquire the necessary data. When comparing satellite systems with aircraft systems the investigator must also remember that aircraft systems, while providing better spatial data, and often spectral data are generally much more difficult to geographically reference to base maps, are more expensive to acquire, and are not usually associated with historical data from the same sensor. Satellite systems collect data continuously thereby, creating an irreplaceable data base, but again with not as good a spatial resolution. Satellite systems are also more sensitive to clouds, fog, and clear sky water vapor. Airborne sensors which are pertinent to temperature measurements are described in Table 1.

Consider the problems of measuring the surface temperature of estuaries, large lakes and river outflows. For a problem of this magnitude, one could utilize the TIROS-N Advanced Very High Resolution Radiometer (AVHRR). For smaller water bodies an aircraft thermal scanner would be used. To measure absolute water temperatures one must conduct the following analyses;

a) Radiometric Calibration - calibrate the sensor output to temperature in Degrees Kelvin.

b) Geometric Correction - map each pixel (picture element) into correct geographic coordinates.

c) Atmospheric Correction - correct the temperature measurements for absorption by water, carbon dioxide, ozone molecules, and short range look angle effects.

d) Determination of Absolute Temperature - if using a dual channel thermal sensor, subtract effects of atmosphere relative to both channels (i.e., Channels 3 and 4 on TIROS-N) or use in-situ derived atmospheric soundings of water vapor.

e) Image Display - as output in human readible form and/or analyze automatically using software driven segmentation procedures to locate water masses.

TABLE 1. Spectral and spatial resolutions and repetition rates of the most applied satellite and aircraft thermal sensors.

SENSOR CHARACTERISTICS	TIROS-N	GOES	LANDSAT-3	AIRCRAFT
Spectral Resolution	3.5-3.9 μm	10.5-12.6 μm	10.4-12.6 μm	Controlled*
	10.5-11.5 μm	--	--	--
Spatial Resolution	1.1 km	8.0 km	.2 km	Controlled
Repetition Rate	6 hrs.	.5 hrs.	18 days	Controlled

*Generally approximately 8-14 μm.

If one is not interested in absolute temperatures, but rather thermal surface features such as plumes or water mass boundaries, one can usually neglect step c (atmospheric correction). Steps a, b and d are the same and the next step is;

f) Image Enhancement - use interpretation or segmentation techniques to locate water mass boundaries and possible semantic analysis to identify plumes by their shapes and proximity to known features.

One must also insure that data are acquired which characterizes the specific problem of interest. The following are some of the major environmental parameters that must be considered if one is to monitor a thermal plume [2];

1) Seasonal conditions - to catch the river at high (flooding) or low flow with little associated runoff, or at specific times of the year when climate cools or warms water in associated drainage basins, or when river water is coldest thereby enhancing the

contrast between the effluent plume and the colder receiving water body.

2) Tidal Cycles - to study the distribution (pattern) of a plume under varying tidal conditions.

3) Atmospheric Conditions - study water patterns (plumes) under the effects of storm surges, high and low wind conditions.

4) Occurance of Specific Activities - at times when a plant is and is not emitting effluents, or during certain dredging or maintenance operations.

5) Land-use features - land-use and cover parameters effect water temperature whether the interpreter is looking for specific structures (buildings such as power plants) or various vegetation communities covering a stream.

Let us next examine in more detail some of the factors related to the analysis of thermal surface features which include;

1) Delineation of land/water boundaries - the infrared (IR) region of the spectrum is generally best for the purpose of establishing this boundary, because the IR reflects off of land features and is generally absorbed by water. This phenomena creates a zone of high contrast. Thermal data collected at night is another way to determine this boundary, for land cools faster than water, so at night the water is warmer and, therefore, brighter than neighboring land features. One must remember that only the upper millimeter or so of the water surface temperature is monitored.

2) Thermal plumes generally have the following characteristics:

   a) Surrounding background (i.e., river, reservoir) is usually different (cooler) than effluent or thermal plume.

   b) Thermal sensor detects variations in thermal response of the target waters generally with an accuracy of from .5 to 1.0° C after it is calibrated.

   c) Variations of temperature are displayed in shades of gray or color; water temperature boundaries are generally also visible at this time.

   d) Boundaries can be outlined manually or automatically by use of segmentation software which descriminates between two classes or differences of water temperature.

e) Hottest (or most extreme temperature) water is then traced (manually or automatically) to a certain point which is the outfall (origin or in this case the point source of the thermal effluent).

f) Direction of main water body flow can be determined in the following ways;

   1) Geographic reference information (i.e., rivers/flow toward the sea).

   2) Plumes entering a moving water body flow in the same direction as the major water body.

   3) Effluent plumes entering a still (stagnant) water body tend to be more evenly distributed across the receiving water body.

g) Having identified the necessary water patterns the interpreter then focuses upon the interpretation of land features that are suspect of causing the thermal plume. One may look for several of the following parameters (which are usually conducted manually, but can be approached automatically);

   1) Structures - nuclear reactor plants are usually located in the immediate vicinity of the receiving water body, generally have cooling ponds, and have characteristic structures (i.e., massive circular cooling towers); numerous industrial complexes along rivers also often have large buildings and associated thermal effluents.

   2) Long, cleared, straight, linear features through marshes or other vegetation cover types that lead from the source of the plume in the water body to an industrial looking facility (i.e., large buildings, stock piles of raw materials). Such a linear feature would indicate the presence of an underground pipeline.

   3) Thermal effluents (plumes) occuring in the middle of a body of water indicates the presence of a pipe which carries the effluent from the shore out into the receiving body of water thereby more evenly distributing the effluent.

4) Thermal effluents in remote areas, without the presence of manmade structures generally indicate natural leakage of a geothermal nature (i.e., underground springs).

5) Water flowing from various drainage basins may also differ in temperature. Tree covered water bodies are often many degrees cooler than water subjected to the direct rays of the sun. On a more macro-scale [3], when observing the Gulf of Mexico in the winter, estuaries draining the northern U. S. are noticeably cooler than estuaries draining the warmer areas of Mexico and Texas (Fig. 3).

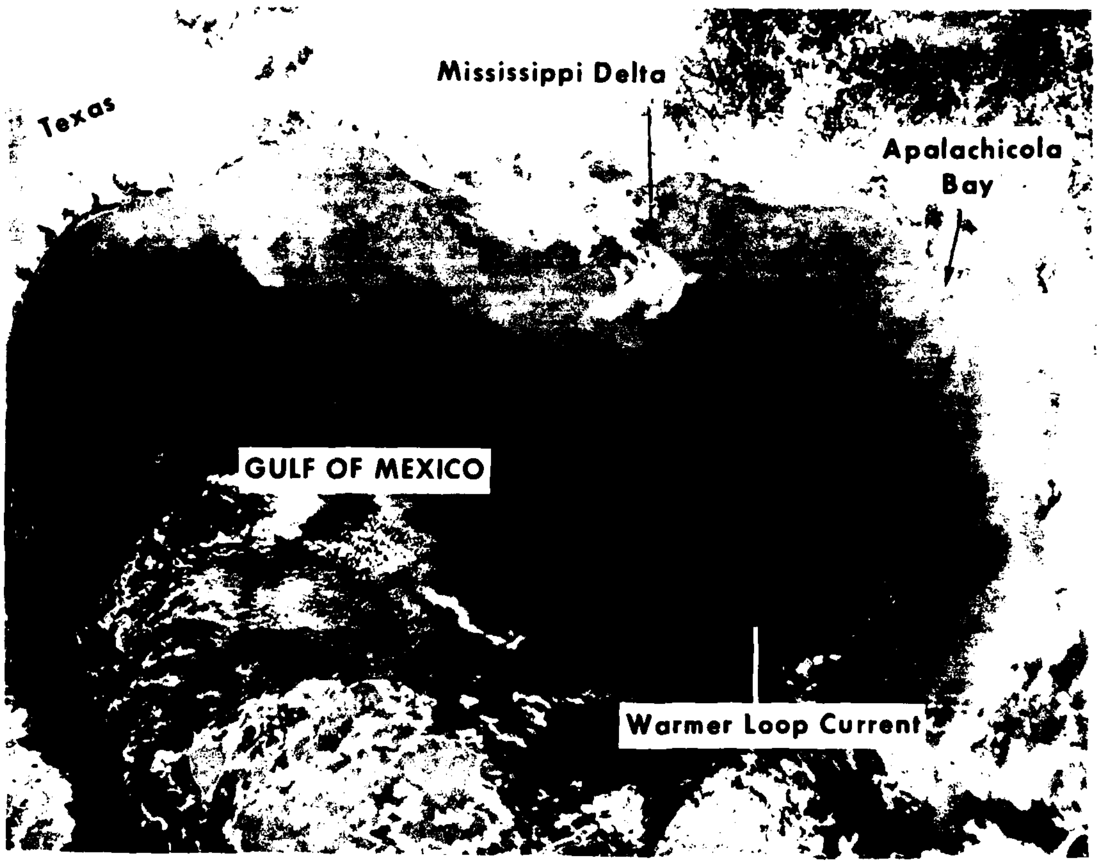


Figure 3. NOAA-3 Thermal IR Image (13 Feb 1976) of Gulf of Mexico Depicting Thermal Plumes

It should be noted that many of these features are semantic in that they require an understanding of the scene. A sophisticated computer analysis system would provide a means for systematically utilizing semantic information.

Another issue in the determination of water quality is the more complicated task of monitoring water color. Water color can be an indicator of, to name a few, productivity, chlorophyll content, turbidity, suspended solids, pH, dissolved oxygen, salinity, light extinction, and even water depth, bottom communities, and various hydrodynamic features of a water body (Fig. 4). It is interesting to note the tremendous variation in scale of Apalachicola Bay, Florida as viewed by two different satellite systems in Figures 3 and 4.

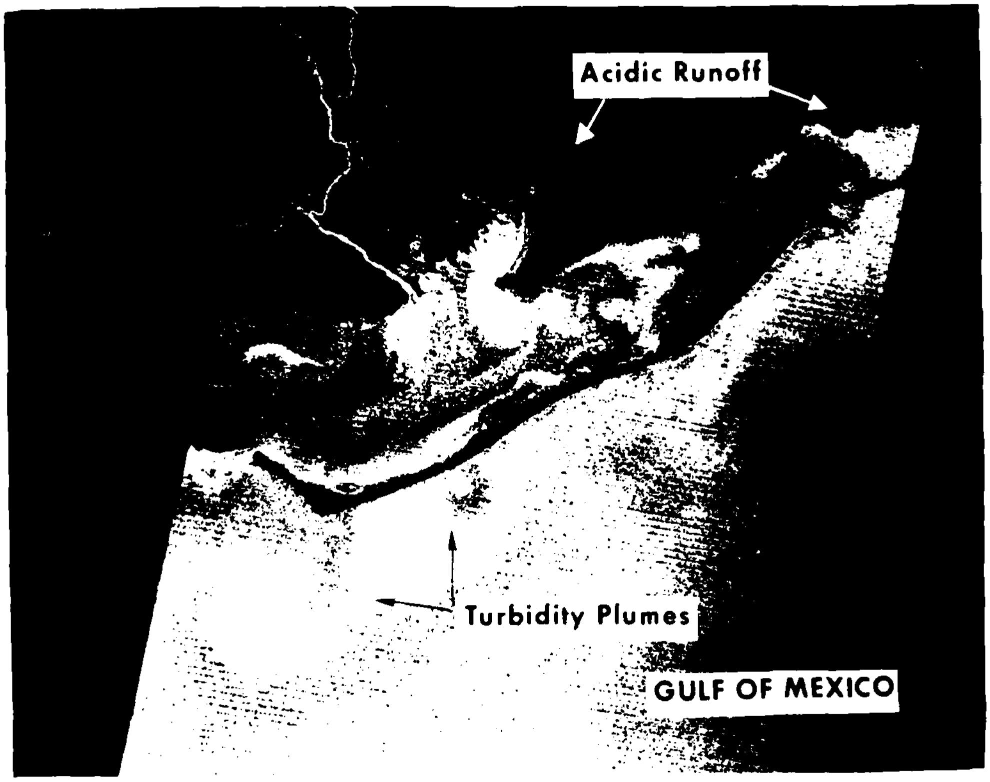


Figure 4. Classified Landsat Image of Water Color Distributions

(26 Feb 1975, in Apalachicola Bay Florida under low wind and near ebb slack tide conditions [source; Hill 1978])

III. IMAGE SEGMENTATION AND TEXTURE ANALYSIS

Image Segmentation and Texture Analysis are among the more complex image processing tasks. The purpose of this section is to review these two areas of image analysis. As stated previously, segmentation relates directly to many military applications where the process is called target location. Texture analysis is important because much of the data from remote sensors is composed of textured patterns. Common examples are scenes of forests and vegetation.

The concept of texture might be described as a grainy, fibrous or woven pattern as opposed to a homogenous or constant pattern. Texture represents the surface of a structure as distinct from color or form. Texture appears to depend upon three ingredients: (a) some local "order" is repeated over a region which is large in comparison to the orders size, (b) the order consists in the non-random arrangement of elementary parts, and (c) the parts are roughly uniform entities having approximately the same dimensions everywhere within the textured region.

The notion that texture depends upon the repetition of local image order must be applied with caution. In most practical cases, the local order or pattern that is being repeated is not identical from place to place, as in wallpaper or linoleum. Rather, the local pattern has similar properties from place to place; usually no two patterns within the texture field are identical. What is being replicated, therefore, is a pattern class within which all examples are regarded as being equivalent. Furthermore, the spatial periodicity of the replication process is seldom perfect. Individual local patterns may suffer spatial phase shifts with respect to the overall matrix. Or, the matrix underlying the textural periodicity may be stretched and twisted (as in fabric). Or there may be no tendency at all toward periodicity other than that produced by the interaction of complex natural forces, as in aerial terrain scenes.

Segmentation

Image Segmentation is a difficult and as yet not well understood task. Often in discussing image segmentation, the topics edge detection, region formation, early vision, semantic methods, top-down, and bottom-up analysis are featured. Edge detection refers to the location of object boundaries. Region formation refers to locating areas of the region which share some property such as uniform gray shade or texture. Early vision refers to image segmentation techniques that do not use semantic models of the image class. Semantic techniques utilize a model of the image class to guide the processing. Top-down techniques analyze the scene first using gross properties of the image and later using finer details. Bottom-up techniques utilize the details of the image first.

This discussion will review these topics.

Region formation, sometimes called region growing, developed somewhat later than boundary formation [4,5]. The purpose is the same, namely to locate the objects of interest in the image. However, the methods are quite different. In region analysis one is attempting to locate areas of the image that share some uniformity property, for example uniform gray shade or texture. The motivation for region formation was that it should be easier to locate areas of uniformity than to trace a boundary of objects by analyzing gradients. Intuitively, tracing boundaries seems more difficult in complex scenes where a number of objects may intersect in a wide variety of patterns. As in boundary formation region formation is influenced by the semantic content of the images. Therefore at some point in the analysis semantic models must be used. It is, however, beneficial to restrain from using semantic models at an early stage since this limits the generality of the system.

There are a number of region formation techniques that are relatively straightforward and yet sometimes effective. These methods usually involve variations on thresholding techniques. Thresholding might be simply stated as picking thresholds $T_\phi,\ldots,T_k$ and connected regions $\{R_{ij} | f(x,y)$ is between T_{i-1} and T_i if (x,y) is in $R_{ij}\}$ where $1 \leq i \leq k$. In using techniques based upon thresholding one must develop an algorithm for selecting the thresholds and one must also determine the area of the picture in which to use the threshold. It is seldom true that a threshold applied over an entire image will give the desired results. Whether thresholding will be at all effective depends upon the image class. Quite often images will have areas that are relatively uncomplicated and therefore thresholding can be used. It should be noted that even for simple scenes often a threshold applied across an entire image will not give the desired results because of subtle variations in the background of the object such as those caused by shadows or variations in the response of the camera. The area of the image in which thresholding will give satisfactory results usually must be selected using higher level control information such as that obtained from semantic models or human interaction. A fundamental idea in thresholding is that the histogram of gray levels can be used to select thresholds.

Reference [6,7] describes a method for selecting subareas of the window using gradients. The essence of the method is to pick areas with high gradients. This method has been called the p-tile method. If the area is one with the gradients above a certain p-tile then the points in the area should be drawn from two sample populations: the object and the background. The problem is that as the p-tiles are increased the shape of the histograms will change. One must then select the p-tile that gives the best histogram.

A variation on this method is described in [8] for multimode segmentation. This method examines clusters in a gray level versus edge value histogram. The two dimensional histogram of GL-EV shows populations with similar gray levels and edge values.

Examining thresholds is a special case of clustering [10]. A clust- ing approach is given in [11]. Methods are described for selecting the number of clusters in the feature space, for example texture measures. The Bhattacharyya measure is used to select the proper features once the clusters are determined. Clustering is again preformed on the reduced feature set and then the pixels are placed in regions according to the clusters.

More advanced segmentation techniques are given in references 12-17 where function approximation theory and semantic information are utilized.

One should note that the methods described mostly utilize the picture gray level g(x,y). The use of the texture as a primitive operator should yield improved segmentation techniques. There are a large number of recent survey articles on texture, reference [18], that one can consult for background information on texture. Reference [19] utilizes texture analysis in a split-and-merge approach to segmentation. A difficulty in applying texture analysis operators is the difficulty of generalizing the gray level quantity g(x,y). In [19] one generalizes the concept by using the intermediate matrices of the texture analysis algorithm and using distance measures between matrices. One would like to ensure however, that the distance measure relates to texture perception in the same way the gray level g(x,y) does in other work on segmentation.

Texture Analysis

There are very important problems confronting an investigator in the automatic analysis of textures. These are:

> Given a number of texture classes, say $C_1,\ldots,C_n$, and given a texture from one of these classes, determine to which textural class this texture belongs. This is the problem that has been the most extensively investigated [17-30].
>
> Given a number of textures, determine the perceptual groupings of these textures where textures which are visually similar are put in one group and other textures which are visually similar are put in another group.

The keywords in the above problem descriptions are "visually distinct," "perceptual groups," and "visually similar." One can define heuristic measures and hope that the statistical measurement selection routines and pattern classification schemes will yield acceptable percentages of correct classification. This procedure has often been followed by investigators employing statistical approaches to texture analysis. The result has been sets of statistical features which are difficult, if not impossible, to translate into any visually perceivable characteristics of images.

Even investigators employing structural approaches to automatic texture analysis have run into problems. On the structural level a texture is considered to be defined by subpatterns which occur repeatedly according to well-defined placement rules within the overall pattern; concepts which seem visually meaningful. The problems encountered have been succinctly stated by Hawkins in [20]. He states:

> First, the notion that texture depends upon the repetition of local image order must be applied with caution. In most practical cases, the local order or pattern that is being repeated is not identical from place to place, as in wallpaper or linoleum. Rather, the local pattern has similar properties from place to place; usually no two patterns within the texture field are identical. What is being replicated, therefore, is a pattern class within which all examples are regarded as being equivalent. Furthermore, the spatial periodicity of the replication process is seldom perfect. Individual local patterns may suffer spatial phase shifts with respect to the overall matrix. Or, the matrix underlying the textural periodicity may be stretched and twisted (as in fabric). Or there may be no tendency at all toward periodicity other than that produced by the interaction of complex natural forces, as in aerial terrain scenes.

Further, the problem of locating the unit pattern even in a perfectly repetitive texture may be complicated by the fact that these unit patterns, themselves, may be made of structured elements, or, more generally, of subpatterns.

In order to apply texture algorithms to segmentation problems one needs to generalize the gray level concept, $g(x,y)$, that has been used in the segmentation methods described in the previous section. In order to make a generalization one needs to have a method for determining the best neighborhood for performing the analysis. Note that for gray level analysis a pixel is used but this is inadequate for texture analysis. Also one needs to measure the similarity of texture patterns. That is, measure $\bar{m} = m_1, m_2, \ldots m_k$ must be extracted from a neighborhood, unit cell C, that relate to perceived differences in textural patterns. Let $\bar{m}(C)$ be the measures extracted form cell C. Then a distance measure must be defined such that $|D(\bar{m}(C_1)) - D(\bar{m}(C_2))| < |D(\bar{m}(C_2)) - D(\bar{m}(C_3))|$ when the perceived texture pattern on C_2 is closer to the pattern on C_1 than on C_3. In other words if the patterns are close, then the measurements should be close. When one has a suitable measure for pattern closeness, then one detects clusters or examines regions for merging or splitting.

A number of texture analysis methods have been proposed. These include the Spatial Gray Level Dependence Method (SGLDM), the Gray Level Difference Method (GLDM) and the Power Spectral Method (PSM).

Some results have been obtained on the ability of the various algorithms to discriminate texture patterns. The motivation for a comparison of texture analysis algorithms is clear since the first choice an investigator faces when attempting to solve an application problem is the selection of the algorithm to be used. A comparison was done in reference 21 where it was shown that the SGLDM texture analysis algorithm had the most texture pattern discriminatory power. These results are valid merely assuming the texture patterns arise from translation stationary random fields of order 2.

IV. CONCLUSION

A wide variety of issues pertaining to remote sensing and image analysis have been considered. The basic topics have been surveyed and placed in perspective according to typical problems encountered by the Corps of Engineers. A typical example in water quality has been considered in some detail. The difficult image processing tasks, segmentation and texture analysis have been discussed in some detail.

REFERENCES

[1] Corps of Engineers. (1979) Remote Sensing Applications Guide. Waterways Experiment Station. Engineering Pamphlet. 70-1-1.

[2] Hill, J. M., 1978. Landsat Assessment of Estuarine Water Quality with Specific Reference to Coastal Land-Use. Ph.D. Dissertation, Texas A & M University.

[3] Huh, O.; L. J. Rouse, and G. Smith, "Surface Temperature and Temperature Gradiant Features of the U. S. Gulf Coast Waters," Proc. of 11 International Symposium on Remote Sensing of Environment, April 1977 (In press).

[4] Zucker, S. W., "Survey Region Growing: Childhood and Adolescence," Computer Graphics and Image Processing 5, pp. 382-399 (1976).

[5] Riseman, E. M.; Michael A. Arbib, "Survey: Computational Techniques in Visual Segmentation of Static Scenes," Computer Graphics and Image Processing 6, pp. 221-276 (1977).

[6] Weszka, J. S.; R. N. Nagel and A. Rosenfeld, "A Threshold Selection Technique," IEEE Trans. on Computers, C-13, 12 (Dec. 1974) pp. 1322-1326.

[7] Weszka, J. S., "Survey of Threshold Selection Techniques," Computer Graphics and Image Processing. (1978) pp. 259-265.

[8] Milgram, D. L.; M. Herman, "Clustering Edge Values for Threshold Selection," University of Maryland Computer Science Center, TR-617, January 1978.

[9] Ohlander, R., "Analysis of Natural Scenes," Ph.D. Thesis; Carnegie Mellon University, Pittsburg, Pa., June 1975.

[10] Schacter, B. J., L. S. Davis and A. Rosenfeld, "Scene Segmentation by Cluster Detection in Color Spaces," Sig-Art Newsletter, No. 58, June 1976.

[11] Coleman, Guy B., Harry C. Andrews, "Image Segmentation by Clustering," Proc. IEEE, Vol. 67, No. 5, May 1979, pp. 773-785.

[12] Pavlidis, T., "Segmentation of Pictures and Maps through Functional Approximation," Computer Graphics and Image Processing 1, 1972, pp. 360-372.

[13] Kelly, M. D., "Visual Identification of People by Computer," Ph.D. Thesis, Stanford University, 1970.

[14] Harlow, C. A., "Image Analysis and Graphics," Computer Graphics and Image Processing 2, 1973, pp. 60-82.

[15] Pavlidis, T., Structural Pattern Recognition, Springer-Verlag: 1977.

[16] Horowitz, S. L.; T. Pavlidis, "Picture Segmentation by a Tree Traversal Algorithm," JACM 23, pp. 368-388, April 1976.

[17] Levine, Martin D., "A Knowledge-Based Computer Vision System" R-77-3 (Oct. 1977), Dept. of Electrical Engineering, McGill University, Montreal Canada.

[18] Haralick, Robert M., "Statistical and Structural Approaches to Texture," Proc. IEEE, Vol. 67, No. 5. pp. 786-804.

[19] Chen, Patrick, Pavlidis, T., "Segmentation by Texture Using a Co-Occurence Matrix and a Split-and-Merge Algorithm," Computer Graphics and Image Processing, Vol. 10. 1979. pp. 172-182.

[20] Hawkins, Joseph K., Textural Properties for Pattern Recognition," from Picture Processing and Paychopictorics. B. D. Lupkin and Azriel Rosenfeld, Ed., New York and London, Academic Press, (1970), pp. 347-370.

[21] Conners, R. W.; C. A. Harlow, "A Theoretical Comparison of Texture Algorithm," IEEE Transaction on Pattern Analysis and Machine Intelligence, To Appear.

REMOTE SENSING OF COASTAL PROCESSES AND RESOURCES

V. Klemas
College of Marine Studies
University of Delaware
Newark, Delaware 19711

ABSTRACT

Remote sensing techniques from aircraft and satellites are being applied to accomplish the following in coastal and estuarine areas:

- mapping wetland boundaries, plant species diversity and productivity;
- monitoring man-made and natural changes in the coastal zone, including the impact of land use change on the environment;
- charting current circulation, waves and other dynamic properties, related to coastal erosion and storm damage assessment;
- determining the identity, concentration and dispersion of certain natural substances and pollutants, such as suspended sediment and oil slicks;
- mapping chlorophyll and nutrient-rich upwelling regions important to fisheries resources management.

These applications of remote sensing require a wide assortment of data analysis techniques ranging from visual photo-interpretation of color infrared film for wetland plant type mapping, to standard digital techniques for thermal mapping, to multispectral analysis methods for marsh biomass mapping, to sophisticated principal component analysis approaches for quantitative analysis of chlorophyll concentration in water. The objective of this paper is to illustrate by means of specific examples how the various multispectral analysis techniques can be employed to process remotely sensed data in order to solve environmental and resource management problems in the coastal zone.

SUMMARY

Remote Sensors on satellites and aircraft are being applied by the University of Delaware to accomplish the following in coastal and estuarine areas:

- mapping wetland boundaries, plant species diversity and productivity;

-comparing training site and spectral signature techniques for mapping coastal vegetation and its productivity;

-monitoring man-made and natural changes in the coastal zone, including the impact of land use change on the environment;

-predicting on-shore impact of Outer Continental Shelf development along the Delaware coast by comparing to similar development along the Louisiana and Alaska coasts;

-charting current circulation and other dynamic properties, related to coastal erosion and storm damage assessment;

-mapping suspended sediment concentrations in coastal waters;

-verifying and improving oil drift/dispersion prediction models for Delaware Bay, including the effects of estuarine fronts on oil slick behavior;

-determining the movement and dispersion of ocean dumped waste plumes and correlating with ship and drogue data;

-mapping chlorophyll and nutrient-rich regions important to fisheries resources management.

These applications of remote sensing require a wide assortment of data analysis techniques ranging from visual photo-interpretation of color infrared film for wetland plant type mapping; to standard digital techniques for thermal mapping; to multispectral analysis methods for marsh biomass mapping; to sophisticated principal component analysis approaches for quantitative analysis of pollutant concentration in water. The objective of this paper is to illustrate by specific examples how various remote sensors and multispectral analysis techniques can be employed to solve environmental and resource management problems in the coastal zone.

Multispectral Analysis of Coastal Vegetation and Productivity

Studies of land cover distribution along Delaware's coast -- especially in tidal wetlands -- have been made, utilizing automated analysis of LANDSAT MSS digital data. Cover maps with eleven vegetation and other cover categories have been produced with accuracy of identification above 85% in all categories. More recent studies have tested new techniques for training automated analysis which use in situ measurements of target radiance and an atmospheric correction procedure to derive reflectance signatures for land-cover categories in preference to the relative radiance signatures traditionally derived from training samples within the satellite data itself. A Bendix Radiant Power Measuring Instrument (RPMI) was used to measure upwelling and downwelling irradiance in the field, allowing computation of target reflectance in the four LANDSAT/MSS spectral bands.

Land cover categorization of data from the same overpass in four test wetland areas was carried out using a wetland category classification system. The tests indicate that training data based on in situ reflectance measurements and atmospheric correction of LANDSAT data can produce comparable accuracy of categorization to that achieved using more conventional relative radiance training. The analysis of the four wetlands cover categories (Salt Marsh Cordgrass, Salt Hay, Unvegetated and Water Tidal Flat) produced overall classification accuracies of 85% by conventional relative radiance training and 81% by use of in situ measurements. Overall mapping accuracies were 76% and 72% respectively. Further refinement of the atmospheric correction and ground measurement procedures should produce better accuracies in a more operational mode.

In addition, field measurements showed that variability in spectral reflectance was, as expected, symptomatic of significant physical characteristics of the test cover types such as time elapsed since tidal inundation of mud, plant height and growth form. Significant correlations were found between single band reflectances and tidal inundation and plant morphologic characteristics. Optimization of seasonal sampling procedures for detection of plant morphologic parameters is suggested.

Modeling and other techniques applied to quantitative assessment of wetland energy and nutrient flux depend, in part, upon accurate data on vegetative species composition and primary production. As shown in Figure 1, recent research in the tidal wetlands of Delaware has shown that spectral canopy reflectance properties can be used to measure the emergent green and total biomass of *Spartina alterniflora* (Salt Marsh Cord Grass) periodically throughout the peak growing season (April through September in Delaware). Such measurements have been applied to calculations of net aerial primary productivity for large areas of *S. alterniflora* marsh in which conventional harvest techniques are prohibitively time consuming. The method is species specific and therefore requires accurate discrimination of *S. alterniflora* from other cover types. Exploitation of seasonal changes in species spectral signatures has also helped improve multi-spectral categorization of wetland cover types in Delaware.

The study was conducted using multi-spectral reflectance measurements in the four LANDSAT/MSS wavebands (4: 0.5-0.6 μm; 5: 0.6-0.7 μm; 6: 0.7-0.8 μm and 7: 0.8-1.1 μm) but has implications for other remote platforms or use of hand-held instruments in the field.

Remote Sensing of Estuarine Fronts and Their Effects on Oil Dispersion

LANDSAT, aircraft and boats were used successfully to study coastal/estuarine circulation and fronts. Fronts (regions of high horizontal density gradient with associated horizontal convergence) are a major hydrographic feature in most estuaries and coastal waters. The water masses separated by a front frequently differ in turbidity and spectral properties, both of which can be observed remotely. Other surface features of fronts which can be imaged remotely include water temperature; wave refraction; foam or debris indicative of convergence; displacement of foam line indicative of lateral shear; displacement of ship wakes or dye lines indicative of longitudinal shear; capture, movement and dispersion of dyes, drogues, or other tracers. Remote Sensors mounted on aircraft or satellites are capable of providing a synoptic view of frontal systems in real-time over large coastal areas.

As shown in Table I, horizontal salinity gradients of 4% in one meter and convergence velocities of the order of 0.4 m/sec. have been observed. Secchi depths changed from one meter to two meters as certain fronts were crossed. Fronts near the mouth of Delaware Bay are associated with the tidal exchange with shelf water. The formation of fronts in the interior of the Bay appears to be associated with velocity shears induced by differences in bottom topography with horizontal density difference in the deep water portion of the estuary (Figure 2). Surface slicks and foam collected at frontal convergence zones near boundaries were found to contain concentrations of Cr, Cu, Fe, Hg, Pb, and Zn higher by two to four orders of magnitude than concentrations in mean ocean water.

A computer simulation model has been developed for tracing oil spills in the Delaware Bay (Wang et al., 1976). The model takes into account two aspects of transport: drifting and spreading. The modeling of drift is based on the fact that oil on water drifts under the combined influence of water current, wind effects, and the earth's rotation. The physical processes governing the spreading of the slick are divided into three stages. In the initial stage, the spreading is predominantly governed by the balance of the forces of gravity and inertia. In the second stage, the spreading involves the balance of viscous and inertial forces. In the third and final stage of the spreading, a turbulent diffusion model is employed. The input requirements include the boundary conditions (the geometry and bottom topography), tidal current, wind conditions, and the nature of the oil spill: viz., the size of the spill, location of the initial spill, and the nature of the oil. Historical tidal current information and present wind conditions in the Delaware Bay region are now being used as input. The interactive nature of the model allows for information transfer between the computer and users who may or may not be familiar with computer programming. The details of oil spill tracking are displayed on a television-type screen.

By capturing and holding oil slicks, frontal systems significantly influence the movement and dispersion of oil slicks in Delaware Bay. Oil slick tracking experiments conducted to verify a predictive oil dispersion and movement model have shown that during certain parts of the tidal cycle the oil slicks tend to line up along fronts. Thus, unexpected oil slick distribution patterns result which even for a known oil type cannot be predicted on the basis of wind and tidal current information alone.

In order to modify the predictive model to include the effect of boundaries on oil slick movement, one must determine where in the Bay boundaries form repeatedly and prevail over major portions of the tidal cycle. Aircraft have been most useful in finding fronts, photographing them, and guiding boats to collect data in frontal zones. However, for tracking the extent and repeatability of fronts over the entire bay under different tidal conditions, satellite imagery is more effective. Imagery and digital tapes from 36 LANDSAT scenes were used in our work. The tidal conditions in each satellite image were matched to one of the 12 National Ocean Survey tidal current charts, where each chart represents current conditions in Delaware Bay during a one-hour segment of the tidal cycle. Thus an average of three satellite images was associated with each of the 12 current charts. The fronts discerned in each image were superimposed on the appropriate tidal current chart.

The identification of fronts was based primarily on strong turbidity gradients or discontinuities. Some of the fronts also have foam lines, temperature gradients, and salinity gradients associated with them. The 12 LANDSAT charts containing current velocities and fronts have been used to establish locations where boundaries tend to prevail. A computer subroutine is being developed for the oil slick drift model in order to handle oil slicks that enter these front-infested areas. The subroutine will include dynamic effects, such as shear currents, at a finer scale.

Drift and Dispersion of Ocean-Dumped Wastes

LANDSAT offers an effective means of assessing the drift and dispersion of certain industrial wastes dumped on the continental shelf. This is particularly true for acid waste disposal about 64 km off the Delaware coast, since this waste forms a sparse but optically persistent ferric floc which can be observed by LANDSAT's multispectral scanner band 4 up to 2 days after dump. The twice-a-week frequency of the dumping made it possible for LANDSAT satellites and aircraft to observe the waste plumes in various stages of degradation, ranging from minutes to days after dump completion. Spectrometric measurements indicate that upon combining with seawater, the waste develops a strong reflectance peak in the 0.55 to 0.60 micron region, resulting in a stronger contrast in the LANDSAT Band 4 than the other bands. This spectral appearance seems to be caused by the formation of a spare but optically persistent suspended ferric floc.

Using sixteen LANDSAT images vector drift diagrams were constructed showing the drift speed and direction of the acid waste plumes. As shown in Figure 3, most of the 16 waste plumes images by LANDSAT were found to to be drifting at average rates of 0.50 km hr^{-1} (0.28 knot) to 3.39 km hr^{-1} (1.83 knots) into the southwest quadrant. The plumes seemed to remain above the thermocline which was observed to form from June through August at depths ranging from 13 m to 24 m. During the remainder of the year, the ocean at the test site was not stratified, permitting wastes to mix throughout the water column to the bottom.

The magnitudes of plume drift velocities were compatible with the drift velocities of current drogues released during the same 12-month period at the surface, at mid-depth and near the bottom. However, during the stratified warm months, more drogues tended to move in the north-northeast direction, while during the non-stratified winter months a southwest direction was preferred. Rapid movement toward shore occurs primarily during storms, particularly northeasters. During such storms, however, the plume is rapidly dispersed and diluted.

The spatial and temporal resolution of the satellite imagery was not sufficient to provide precise data on waste plume dispersion. However, a visual estimate of plume width was obtained from satellite imagery and plotted as a function of time after dump in Figure 4. As shown in Figure 4, the plume width spreading rates range from about 0.5 cm sec^{-1} to about 6 cm sec^{-1}. During calm seas the plume width increased at an average rate of about 1.5 cm sec^{-1}, while during wind-dominated, rough sea conditions, spreading rates in excess of 4 cm sec-1 were attained. On days when wind velocities exceeded 15 km hr^{-1} rapid formation of regular patches (Langmuir cells) was evident. These results are in agreement with Falk's (1974) estimate of plume dilution shown in Figure 5, which indicates that by the time a waste plume moves 28 km from the dump site, dilution is at least about one million to one.

Multispectral Analysis of Water Pollutants and Suspended Sediment Concentrations

Much of what is unique about our approach is an indirect result of the use of LANDSAT/MSS digital data. LANDSAT was not designed for observations in water. The gain is low making the dynamic range of the sensor very limited. The four spectral channels were selected for land use applications and are hardly ideal for water observations. Yet, there is a surprising amount of information in the LANDSAT imagery. As shown in Figure 6, LANDSAT data has been used to map sediment distribution patterns (Klemas, et al., 1977) to observe the occurence of estuarine fronts (Klemas and Polis, 1977) and to observe the occurence of internal waves (Apel, 1974), to cite only a few of the many papers in which LANDSAT imagery has been used in sensing of water.

The use of spectral reflectance characteristics to identify substances in the water has attracted considerable attention in the past several years. Our approach is most similar to that suggested by Mueller (1976) -- eigenvector (pincipal component) analysis. Eigenvector analysis has been described by a number of investigators including Mueller (1976) and Simmonds (1963).

One major reason for using eigenvector analysis is that it allows the reduction of significant variates with minimal loss of information. With LANDSAT/MSS data there are only four spectral bands and therefore only four variables to begin with and the analysis will rarely reduce this number by more than one. However, the eigenvectors can also provide an efficient representation of variations in water color which can be readily adapted to an automatic classification process.

To illustrate the technique one can imagine a body of water, part of which is clear, part of which is heavily sediment-laden and part of which contains pollution of some sort. A LANDSAT image of the area would show the clear water as relatively dark while both the sediment and pollutant would appear relatively bright. The sediment might show up brighter than the pollutant in Band 5 and the reverse might be true in Band 4. If one were to plot the radiances observed in both bands for each picture element (pixel) the result would appear as in Figure 6. The origin represents the clear water pixels and the two lobes represent sediment pixels ($\bar{B}$) and pollutant pixels ($\bar{A}$). Clear water has a particular spectral signature and addition of any material to the water will cause that signature to deviate from the clear water signature -- the more material added, the greater the deviation. If the deviation is in different directions for two materials then they will be distinguishable to some extent. Vectors $\bar{A}$ and $\bar{B}$ represent the first eigenvectors associated with each material. The simplest measure of the spectral separability of the two materials is the angular separation of these two vectors. The eigenvector analysis also provides measures of the dispersion of the data about the axis of the first eigenvectors. The whole procedure is covered in considerable detail by Klemas, et al., (1978).

For our present purposes we will limit ourselves to the angular separation of the eigenvectors as a measure of spectral separability. Table 2 shows the results of analyzing six different coastal Delaware LANDSAT scenes for sediment, ice, clouds and an acid-iron industrial waste. There is some dispersion among vectors identifying each material resulting solely from the use of data acquired on different days. This dispersion amounts to $\sim 6^{\circ}$ for sediment, $\sim 10^{\circ}$ for the acid waste and $\sim 10^{\circ}$ for clouds. The angular separation between different substances is always significantly higher, however: between acid and sediment it is about 35°, between acid and clouds it is about 40°.

To demonstrate what this means in terms of classification, two of these scenes were chosen in which there was some uncertainty as to what was cloud and what was acid. The eigenvector analysis was used to classify each pixel in both scenes as either acid, sediment, clouds or clear water. The results are shown in Figure 7. In Figure 7A the clouds and acid are both plotted as dark points. The light areas correspond to clear water. (Less than twenty points out to tens of thousands were classified as sediment in both cases. These points were treated as clear water.) In Figure 7B only these pixels actually classified as acid-iron were plotted. The pattern that is seen is the course followed by the acid-iron barge while dumping. There is some noise in the background and there are some gaps in the pattern caused by clouds directly over the dump track, but generally the distinction is quite good.

It is likely that this approach can be extended with the LANDSAT data to include several other substances, and that considerably better results could be achieved using spectral channels more appropriate for analysis of water, such as those on the Coastal Zone Color Scanner (Hovis, 1977). LANDSAT image radiance data also was correlated with suspended sediment concentration and Secchi depth data obtained from boats and helicopters during the selected satellite overpasses. A suspended sediment concentration map based on LANDSAT image radiance correlation with water sample analyses is shown in Figure 8.

Feature	Estuarine Tide & Bottom Related	Estuarine Tidal-Wedge	Coastal Wind & Current Induced
Location	Upper & Lower Bay	Lower Bay	Coast & Shelf
Frontal Alignment	Parallel to River Flow Axis	Perpendicular to River Flow Axis	Any Direction
Transverse Velocity (cm/sec)	5-20	10-60	5-40
Transverse Movement (km)	$\pm$ 0.3	$>$ 10	$>$ 10
Convergence Velocity (cm/sec)	5-40	2-20	2-20
Shear Velocity (cm/sec)	5-20	1-5	1-15
Seshi Depth ($m_1 \rightarrow m_2$)	0.4$\rightarrow$1.6	1.0$\rightarrow$2.2	Sometimes
Color Change	Strong	Moderate	Moderate/None
Foam & Oil Capture	Strong	Moderate	Moderate/Weak
Detritus & Dye Capture	Strong	Moderate	Moderate/Weak
Wave, Refraction & Damping	Strong	Moderate	Moderate
Temperature Change (^{o}C)	0-3	0-2	0-2
Salinity Change ($^{o}/_{oo}$ S)	0.5-2	1-4	1-2

*Changes in water properties across fronts were measured from boats or estimated from remotely sensed data along transects across the fronts. Changes indicated were measured over a distance of 10 meters on either side of the front.

**Some coastal fronts exhibit changes in temperature, salinity, turbidity and color as one crosses them, others may have gradients in only one of these parameters or none. Turbidity and color changes become less distinct as one moves out of the bay and onto the shelf.

Table I. Observed Features of Three Front Types

			ACID-IRON WASTE							SEDIMENT				CLOUDS				ICE
			24 FEB 76	19 JAN 76	21 OCT 75	19 AUG 75	17 NOV 75	15 MAR 74	AVERAGE	24 FEB 76 (NORTH)	24 FEB 76 (SOUTH)	19 JAN 76	AVERAGE	19 JAN 76	19 AUG 76	15 MAR 74	AVERAGE	19 JAN 76
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ACID	24 FEB 76	1	--															
	19 JAN 76	2	14.4	--														
	21 OCT 75	3	3.9	13.7	--													
	19 AUG 75	4	12.7	6.2	10.5	--												
	17 NOV 75	5	4.4	13.6	7.8	13.8	--											
	15 MAR 74	6	6.3	10.7	8.6	11.6	3.3	--										
	AVERAGE	7	8.5	11.1	8.6	10.3	8.8	7.9	--									
SEDIMENT	24 FEB 76	8	36.1	22.9	33.9	21.7	36.4	33.5	31.5	--								
	24 FEB 76	9	37.9	24.8	35.7	25.4	38.3	35.4	33.3	2.0	--							
	19 JAN 76	10	34.2	22.6	31.4	21.8	35.2	32.7	30.1	6.1	6.5	--						
	AVERAGE	11	36.1	23.5	33.7	23.6	36.6	33.8	31.8	3.6	3.9	5.1	--					
CLOUDS	19 JAN 76	12	47.2	33.8	45.9	35.7	46.1	42.9	42.2	19.8	18.9	24.1	21.0	--				
	19 AUG 76	13	31.6	18.5	30.8	21.3	30.2	26.9	27.0	16.9	17.8	20.2	18.3	16.2	--			
	15 MAR 74	14	39.4	25.7	38.1	27.8	38.4	35.2	34.5	13.5	13.4	18.0	15.1	8.3	9.2	--		
	AVERAGE	15	39.8	26.7	38.7	28.8	38.7	35.5	35.0	16.9	16.9	20.9	18.3	10.5	10.8	7.2	--	
ICE	19 JAN 76 AVERAGE	16	42.6	28.6	41.1	30.6	41.9	38.7	37.6	11.2	10.5	16.5	13.0	9.4	14.3	5.9	10.4	--

Table II. Angular separation (in degrees) between primary eigenvectors

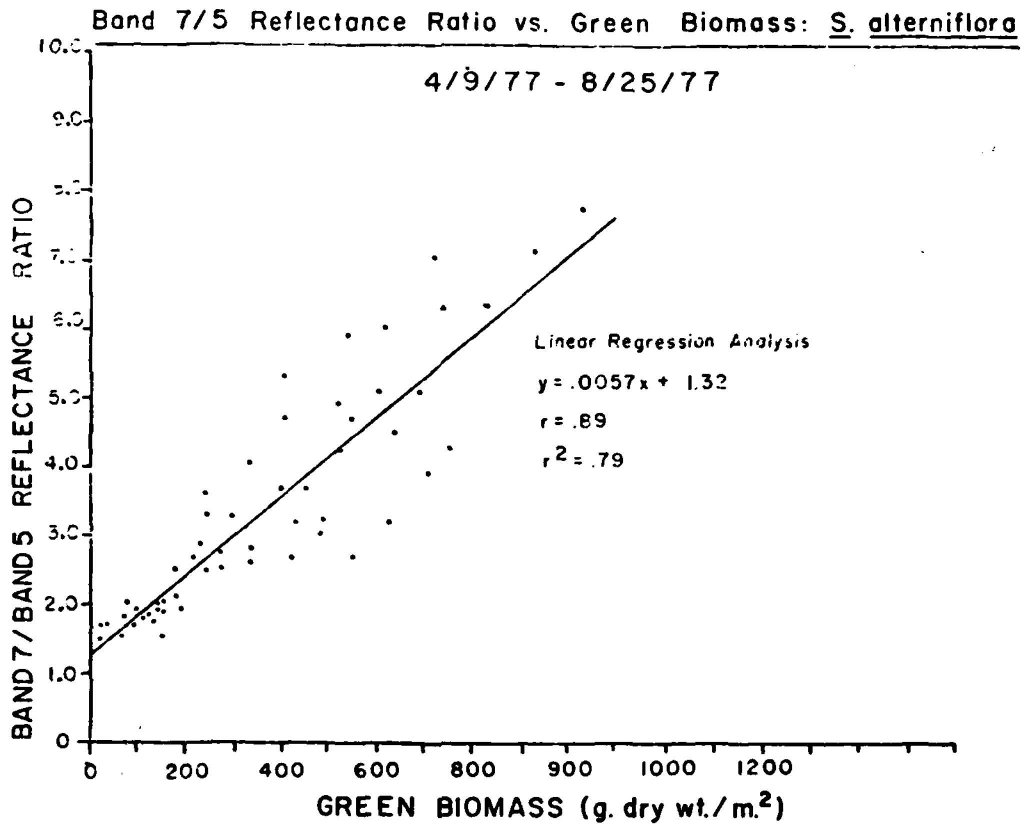


Figure 1. Plot of measured LANDSAT MSS band 7/band 5 reflectance ratio as function of green biomass in grams of dry weight per square meter

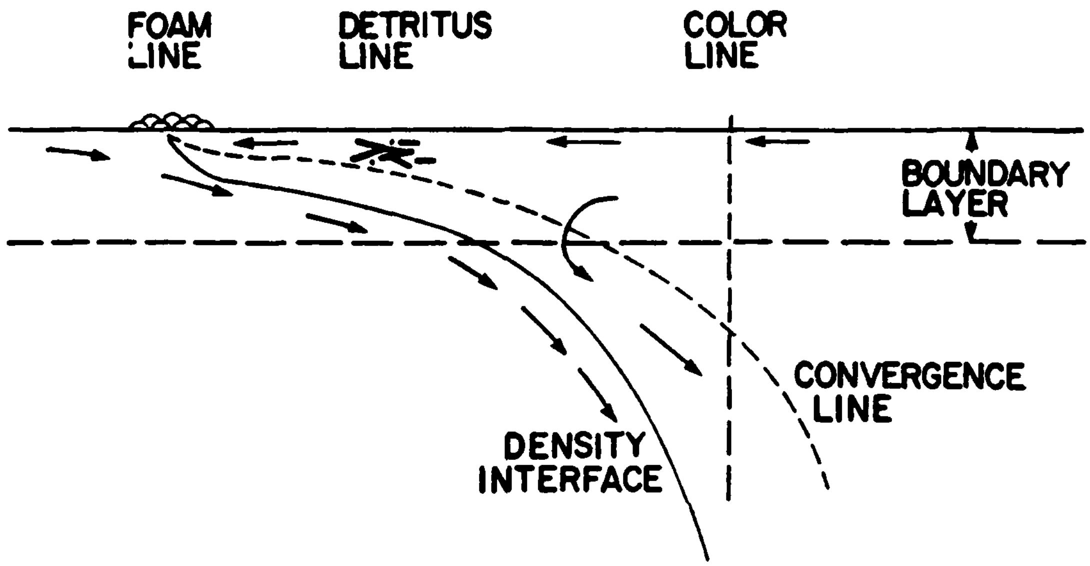


Figure 2. Schematic Diagram of a Vertical Section Perpendicular to a Frontal Convergence Zone. Note Displacement of Surface, Near Surface and Main Zones of Convergence as Marked by Foam, Detritus, and Color Lines Respectively

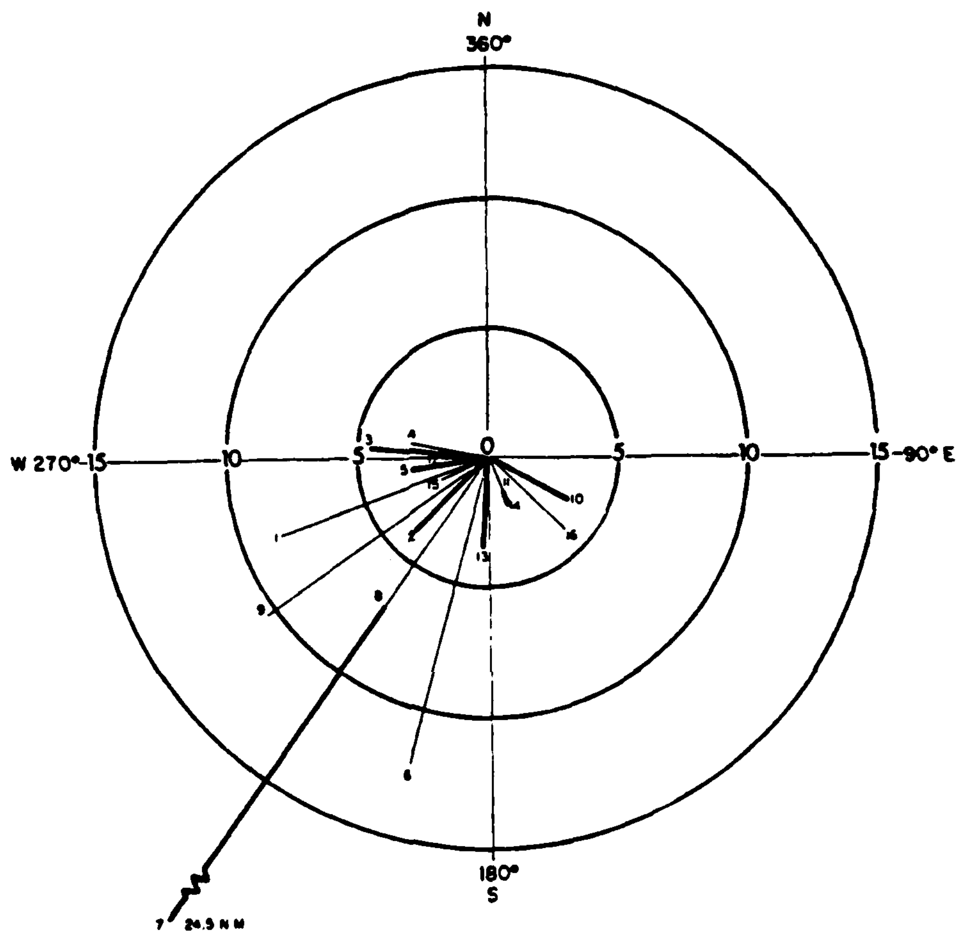


Figure 3. Distance from center of dump site to estimated centroid of imaged plume

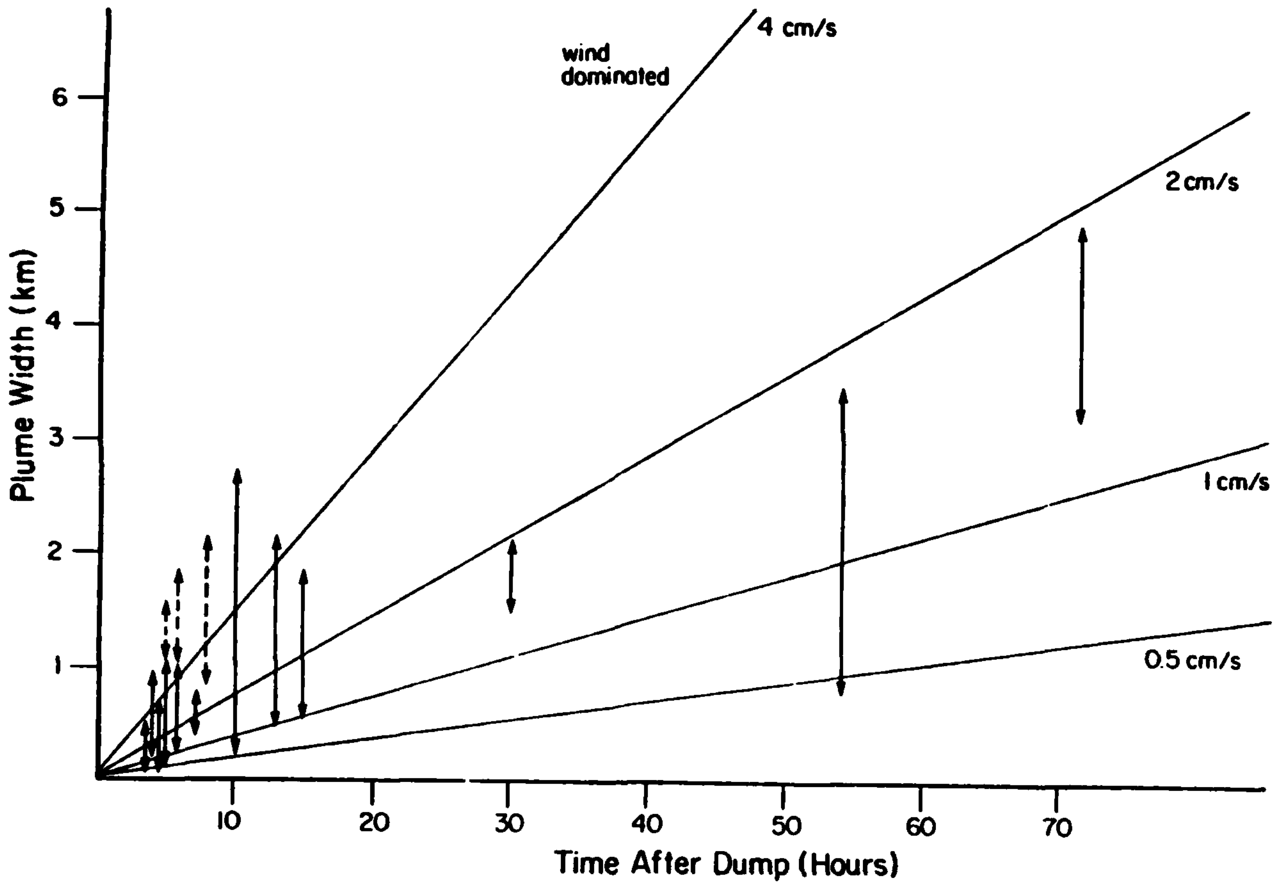


Figure 4. Dispersion of Acid Waste Plume

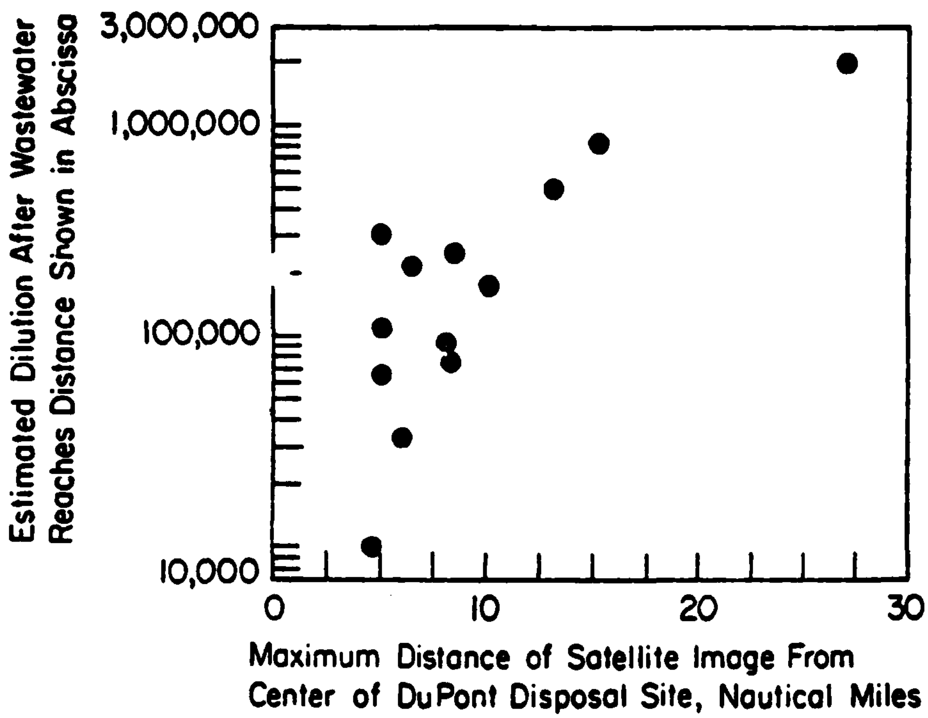

Estimated Dilution After Wastewater Reaches Distance Shown in Abscissa
3,000,000
1,000,000
100,000
10,000
0
10
20
30
Maximum Distance of Satellite Image From Center of DuPont Disposal Site, Nautical Miles

Figure 5

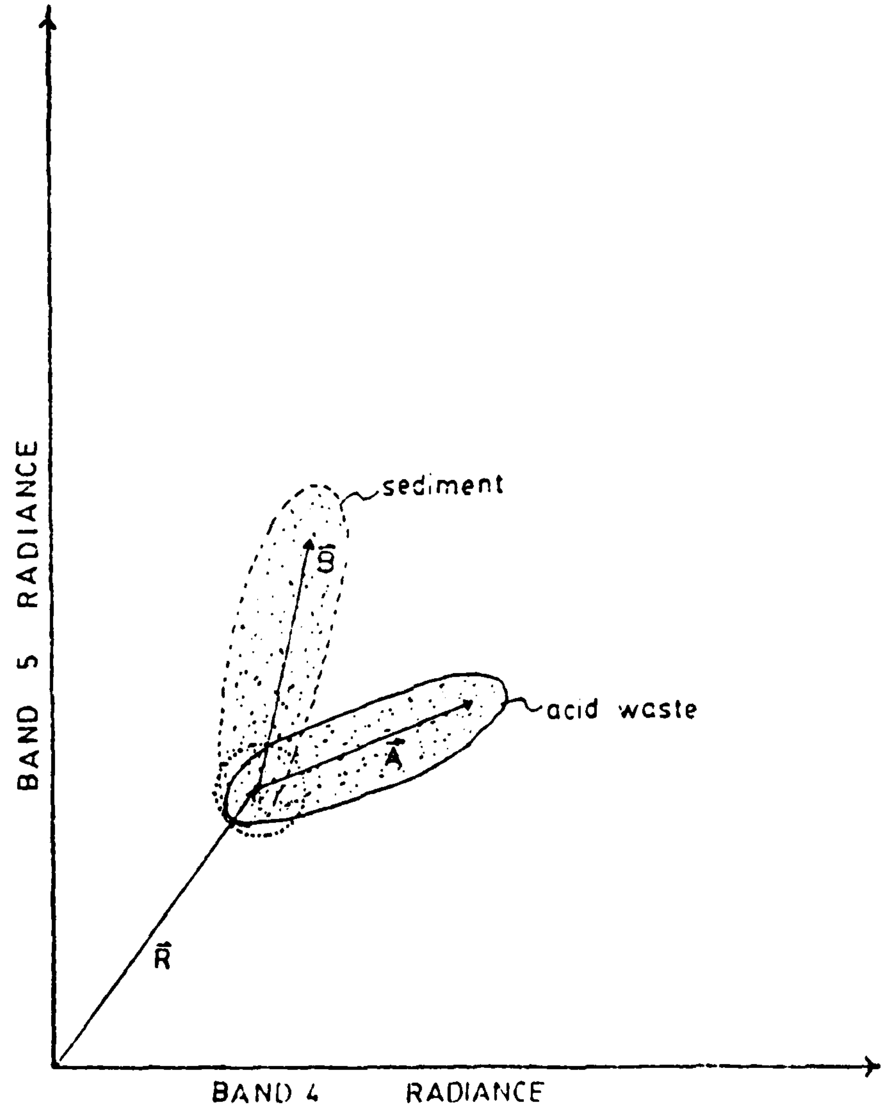


Figure 6. Diagram of the geometry of the eigenvector analysis. The origin has been placed at the position of the "clean" water standard

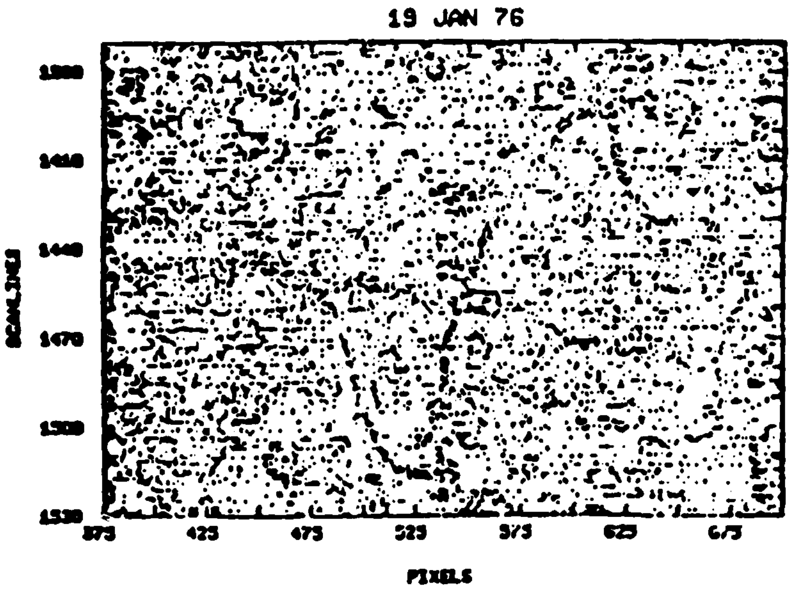


Figure 7A. Iron-acid waste plume imaged by LANDSAT on 19 January 1976 with cloud background

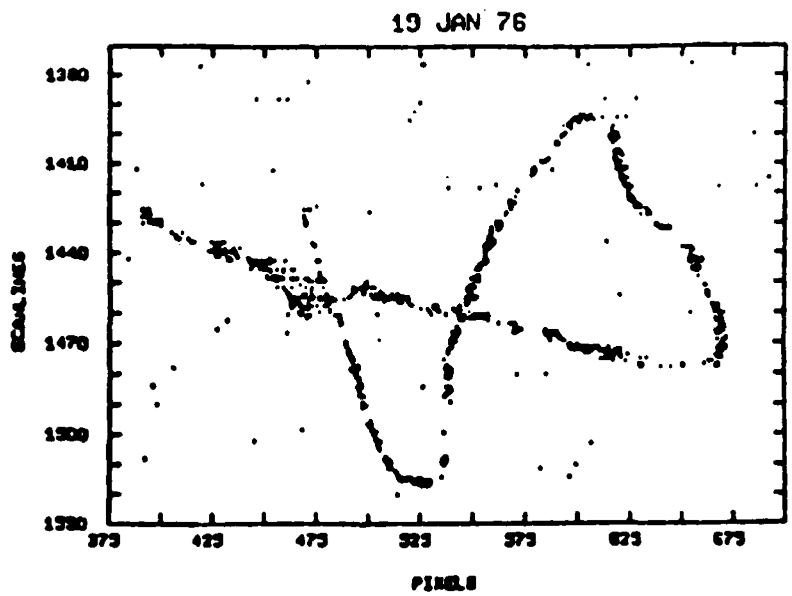


Figure 7B. Enhancement of the iron-acid waste plume of 19 January 1976, against a cloud background

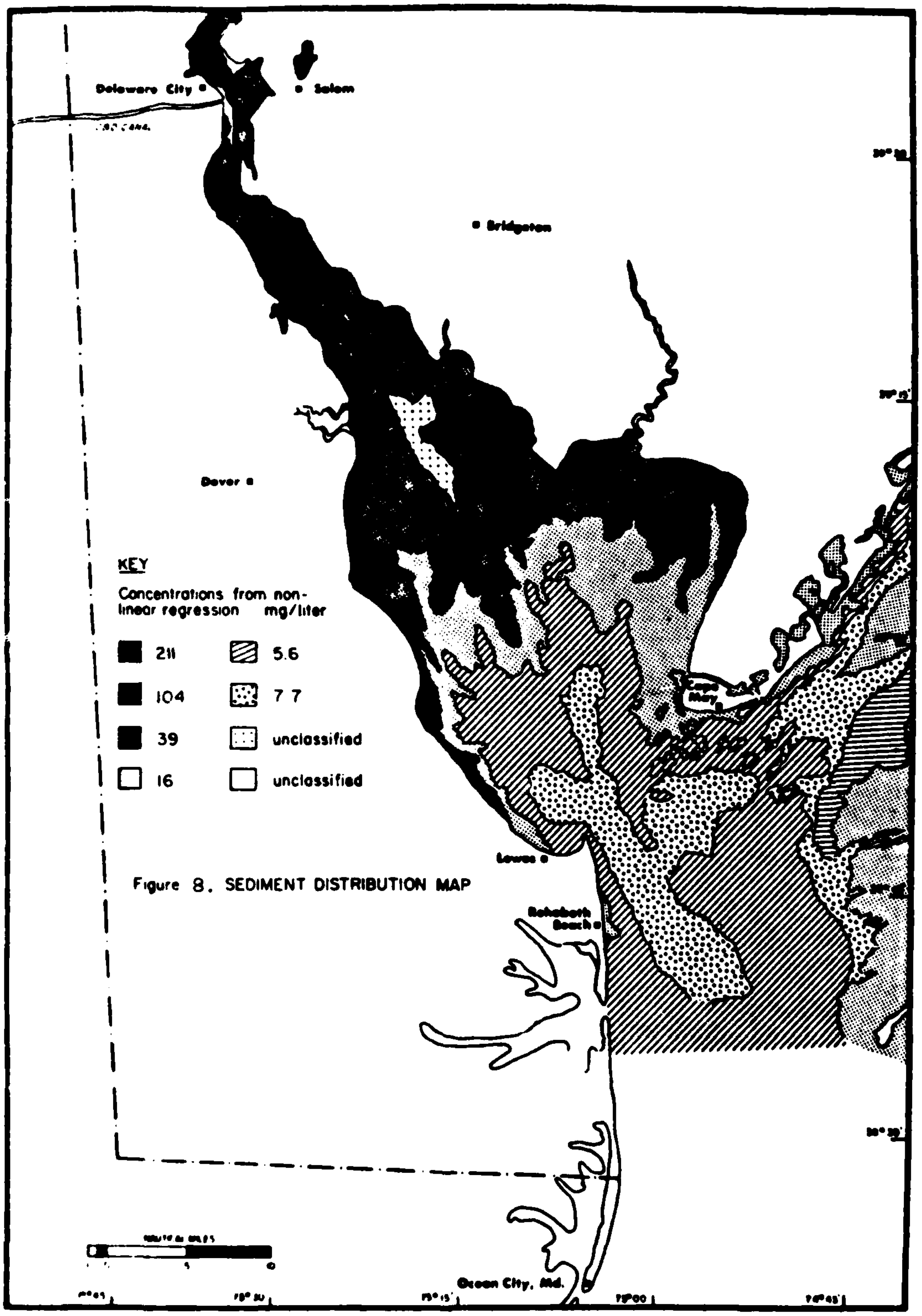


Figure 8. SEDIMENT DISTRIBUTION MAP

REFERENCES

Apel, J.R., R.V. Charnell and R.J. Blackwell, 1974. Ocean internal waves off the North American and African coasts from ERTS-1-Proc. Ninth Intern. Symp. on Rem. Sens. of Environment, Ann Arbor, Michigan, 14-19 April 1974.

Bartlett, D.S. and V. Klemas, Assessment of Tidal Wetland Habitat and Productivity. Proc. of 13th International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, April 23-27, 1979.

Bartlett, D.S. and V. Klemas. Quantitative Assessment of Emergent Biomass and Species Composition in Tidal Wetlands Using Remote Sensing. Proc. of Workshop on Wetland and Estuarine Processes and Water Quality Modeling, New Orleans, Louisiana, June 18-20, 1979.

Falk, L.L., et al. "Waste Dispersion Characteristics and Effects in an Oceanic Environment." Report prepared for U.S. Environmental Protection Agency, Program No. 12020 EAW (1974).

Hovis, W.A., Jr. 1977. Remote Sensing of Water Pollution. Proc. 11th Intern. Symp. on Remote Sensing of Environment, Ann Arbor, Michigan, pp. 361-362.

Klemas, V., C. Davis, J. Lackie, W. Whale and G. Tornatore, 1977. "Satellite, Aircraft and Drogue of Coastal Currents and Pollutants." IEEE Transactions on Geoscience Electronics, Vol. 2, No. 2, pp. 119-126.

Klemas, V. and D.F. Polis, 1977. Remote Sensing of Estuarine Fronts and Their Effects on Pollutants. Photogram. Eng. and Remote Sensing, 43(5); pp. 599-612.

Klemas, V., G. Davis and W.D. Philpot. Remote Sensing of Ocean-Dumped Waste Drift and Dispersion. Proc. of Int. Symp. on Ocean Dumping of Industrial Waste. School of Oceanography, University of Rhode Island, 1978.

Mueller, J.L., 1976. Ocean Color Spectra Measured Off the Oregon Coast: Characteristic Vectors. Applied Optics 15, pp. 395-402.

Philpot, W.D. and V. Klemas, Remote Detection of Ocean Waste, SPIE's Ocean Optics VI - Technical Symposium, Naval Postgraduate School, Monterey, California, October 23-25, 1979.

Simmonds, J.L., 1963. Application of Characteristic Vector Analysis to Photographic and Optical Response Data. J. Opt. Soc. Amer., 55: pp. 968-974.

HISTORICAL SHORELINE CHANGES AS DETERMINED FROM AERIAL PHOTOINTERPRETATION

LAWRENCE W. GATTO

U.S. Army Cold Regions Research and
Engineering Laboratory
Hanover, New Hampshire

SUMMARY

Purpose of the Investigations

The protection and preservation of shorelines and coastal areas along oceans, lakes, reservoirs and rivers have become increasingly important with more intensive use and development of these areas by the growing population. Shoreline erosion and subsequent shoreline recession are of primary concern since they cause property loss, changes in shoreline habitats and degraded water quality. USACRREL has been investigating many of the complex erosion processes, site specific rates of erosion and problems caused by shoreline erosion.

As an integral part of these comprehensive investigations, historical and recent aerial photographs have been used to document historical shoreline characteristics and conditions, to determine past patterns of regional shoreline changes, to monitor the areal extent of shoreline erosion, and to estimate the historical rates of change in shoreline positions.

Approach

Photointerpretation Procedures and Equipment

Standard photointerpretation techniques and equipment were used. Computer analyses were not required for these investigations. A Bausch and Lomb Zoom Transfer Scope was used to determine locations and amounts of shoreline change. A Vernac Direct-Reading Optical Measuring Instrument mounted on a Richards light table was used to measure horizontal distances from shoreline reference points to the bluff break and toe, the highwater line, and the water line.

As an initial step in the analyses, ground and air reconnaissance was required to become familiar with regional characteristics of the study areas prior to air photo analyses. Ground truth surveys were also necessary at some sites to verify photo interpretations.

Photogrammetric Considerations

The following disadvantages of aerial photographs were considered prior to using photos for historical analyses:

(1) photographic scale variations and geometric distortions are common;
(2) photomeasurements are generally not as accurate as ground survey measurements;
(3) shoreline conditions photographed may be atypical, i.e. after a storm, during high water periods, after floods;
(4) photographs available may not have been taken frequently enough or be of a large enough scale to meet project needs; and,
(5) old photographs may be of poor quality, i.e. contrast variations, focus inaccuracies, reproduction degradations.

However, some of the effects of these limitations were reduced by

(1) using geometrically corrected and rectified photos to reduce the measurement errors that result from distortions; and
(2) making measurements in the middle portion of the photos where distortions and variations are minimal, if corrected photographs are not available.

In spite of the limitations, there are several advantages to using aerial photography:

(1) a permanent record of shoreline conditions and processes existing at the time of acquisition is obtained;
(2) photos show more detail for historical analysis than maps or charts;
(3) photos provide a regional perspective not available from other sources;
(4) processes active under different conditions can be observed; and
(5) photos may be the only available source of data on historical conditions.

Sources of Aerial Photographs

The availability of photos was determined by searches with the U.S. Geological Survey's EROS Data Center (EDC), National Cartographic Information Center's Aerial Photography Summary Record System, National Ocean Survey, National Aeronautics and Space Administration, Defense Mapping Agency (DMA), Corps of Engineers Districts and Divisions, state agencies and private photo and research firms.

Once the photo search was completed, historical photos were obtained from the EDC, National Archives, U.S. Department of Agriculture's Aerial Photography Field Office, DMA, many of the state agencies and private companies.

Results

Cape Cod, Massachusetts

I used historical aerial photography to determine past patterns and rates of shoreline change along the outer shore of Cape Cod from Long Point to Monomoy Point. The photo data provided estimates of historical rates of coastal erosion which were used as part of the New England Division, Corps of Engineers, beach erosion control study of the Cape.

Great Lakes Connecting Channels

Sequential historical photos were used to determine locations of and estimate rates of shoreline erosion and to document changes in shoreline conditions prior to year-round navigation along the U.S. shoreline of the St. Marys, St. Clair, Detroit and St. Lawrence Rivers. Some of the changes observed were shoreline recession, nearshore accretion, channel and nearshore bathymetric changes, coastal morphology, shoreline development and construction, and sediment or water patterns. This investigation was done in cooperation with the Detroit District. It was part of the District's comprehensive assessment of the effects of the winter navigation season extension program on the shoreline environment.

Corps of Engineers Reservoirs

Historical aerial photos are being used to document previous shoreline conditions and to estimate past rates of shoreline erosion at selected Corps reservoirs in the northern U.S. These data will be correlated with data on water level fluctuations, wind records and annual ice formation and ablation to determine the historical importance of these factors in the erosion process in cold climates. This analysis is part of a program to investigate the unique cold regions processes and environmental impacts of shoreline erosion along Corps lakes and reservoirs.

Applications

Aerial photo data were used to provide data not previously available from other data sources. Frequently, information on historical environmental conditions cannot be obtained from other than aerial photos.

Photo data were used to augment other data to develop design criteria for future construction projects.

The relationships between selected erosion processes and the resulting historical shoreline recession will be evaluated by using photo data and historical records to test correlation.

Data and interpretations from photos will be used to try to develop models that predict the areal extent of shoreline erosion to improve the estimate of the location of a reservoir taking line. This improvement may reduce the legal problems of the Corps at many reservoirs.

Recommendation

When a project is designed as a study of historical shoreline changes, photos may be the only source of data. When analyzing present shoreline changes, aerial photography is a convenient and useful tool to augment conventional techniques of data collection. Although air photo data may not be as accurate as that acquired from field surveys, aerial photographs provide a regional perspective not obtainable from ground surveys. Aerial photographs should be considered as a proven tool for acquisition of many types of environmental data and should become an integral part of environmental analyses based on project requirements.

INTERDISCIPLINARY ANALYSIS OF AERIAL IMAGERY FOR PLANNING STUDIES

by

Paul Soyke and Jill Rakus
Corps of Engineers, Rock Island District

INTRODUCTION

In the spring of 1976, the North Central Division of the Corps of Engineers sponsored a demonstration program at the Rock Island District on the use of interdisciplinary analysis of aerial imagery as a means of obtaining information about the environment useful to the planning and development of civil works projects. The selected study was the Des Moines Streambank Erosion Feasibility Study in Iowa and Missouri. The objectives of this study were to determine the causes of streambank erosion and the feasibility of providing erosion control measures along 143 miles of the Des Moines River downstream of Red Rock Dam.

In order to evaluate the erosion process in light of any historical changes in the basin, an interdisciplinary team was formed consisting of a wide variety of disciplines from the North Central Division of the Corps of Engineers and other Federal Agencies including engineering, economics, law, biology, geology, and forestry. As a first step in the process, the participants were instructed on the techniques of photo interpretation during a one-week course taught by the staff of the US Army Engineering Topographic Laboratory, Fort Belvoir, Virginia.

After the training session, the initial procedure in the program was the regional analysis of the entire study area using 1975 aerial photo mosaics at a scale of 1:30,000. This analysis included stereoscopic methods to determine drainage patterns, land forms, land cover, and cultural features. The study area was then divided into three reaches for more detailed analysis. This detailed analysis used 1:20,000 scale aerial photo mosaics covering periods in about 1938, 1950, and 1969. It included the same type of analysis as used for the 1975 photos but in considerably more detail, especially as it pertained to land cover and the location of the river channel. Selected erosion sites were also identified and analyzed using individual 9-inch by 9-inch photos to determine the progression of river channel change.

The method by which each reach was examined was the systematic interdisciplinary team approach. This procedure, as mentioned before, involves a team of professionals with various disciplines coming together to analyze the physical, biological, and cultural features of the landscape. This type of analysis is based on the fact that stereo-aerial photography records the patterns of the landscape. The members of the team worked closely together to document those physical, biological and cultural characteristics of the study area. The main purpose in using this type of approach is to stress the individual effort, closely examining the environmental changes as shown on the aerial photographs as well as the interdisciplinary team or group approach.

For the Des Moines River Erosion Demonstration Project, uncontrolled photo mosaic boards were developed of the three study reaches for 1938, 1950, and 1969. These boards were used as a basis for showing the changes which took place over a given period of time.

The photo mosaic boards were developed using 9-inch by 9-inch black and white aerial photographs, placed on boards approximately five feet wide by seven feet long. These boards were then covered with clear acetate overlays, which served as drawing surfaces. Using a pocket stereoscope, the participants were then capable of interpreting and recording their observations of the various ground conditions.

Using the 1969 photographs, four overlays were developed for each individual board. The features for which the overlays were made included, the land cover, land forms, the drainage patterns, and the transportation systems.

Each overlay consisted of various figures which represented certain types of conditions. The land cover overlay designated those areas which were presently used for agricultural purposes, from forested and urban areas. Also shown on this overlay were bodies of water, such as farm ponds, any extractive industries, and objects such as levees, sandbars, and riprap.

The symbols used on the land form overlay designated primary soil types and, when possible, showed the locations of various morphologic units, such as abandoned river meanders, and glacial deposits. Geologic columns indicating what types of materials are found in what areas and the relationship between those materials, are also shown on the overlay.

The drainage overlay consists of the entire drainage network for the study area. Of the overlays, the drainage overlay could be considered the most significant. Much additional information can be inferred from this overlay than from the others. Since the drainage and the physiography are controlled to a large extent by the underlying bedrock, the drainage and erosion patterns are valuable indicators for the interpretation of the landscape.

These patterns, drainage networks, gully cross sections, stream gradients, and stream junctures, all have certain characteristics indicative of particular types of materials. When a change in the density, fineness, or angularity of the drainage occurs, the interpreter can assume that a change of conditions or subsurface materials has taken place.

By learning to recognize and associate certain patterns with certain soil types and structural as well as geologic conditions, the interpreter is capable of making accurate assessments of the study area. Man-made drainage can also be noted on the drainage overlay. Drainage features of this type are readily observable and they are not subject to any controlling factors, such as the underlying bedrock. These features also alter the natural course of drainage to some degree, so here again, recording structures such as levees, channels, or farm ponds on the overlay is relatively simple.

The transportation overlay shows the major highways, roads, railroads, transmission lines, and airport facilities.

All of these features are drawn directly on the acetate overlays by the interpreter.

These overlays help the scientists to predict the future use of the area. Interpretation of these overlays can indicate the best land use, and more importantly, the changes in land use, land cover, and transportation systems.

The mosaics were constructed from 9-inch by 9-inch aerial panchromatic photography obtained from US Department of Agriculture, Soil Conservation Service (USDA-SCS) and the National Archives. This was supplemented with selected strips of color infrared transparencies available in the Rock Island District.

After initial interpretation, field sampling was accomplished to examine vegetation, soils, land forms, and cultural features at selected sites to verify the photo analysis and to answer specific questions. Figure 1 shows the location of the study area as well as the reaches studied.

Interdisciplinary photo analysis was used for this study because this procedure records a pictorial representation of landscape patterns which are indicators of materials and events that reflect the physical, biological, and cultural characteristics of the landscape. A given flood plain material will respond to a specific action in a way unique to that particular combination. Each material has its own characteristic pattern that can be recognized on a photograph. The analysis depends on knowledgeable observation of pattern detail associated with tone and shape, and changes within these patterns.

One of the values of interdisciplinary photo analysis is its ability to allow for a rapid and relatively inexpensive survey of a large area in a short period of time. This provides a basis for initial determination and assessment of such important items as environmental flexibility and sensitivity and potential engineering problems, which will be used to determine the feasibility of project development. It also allows project funds to be channeled to those areas which are determined to be critical. Photo

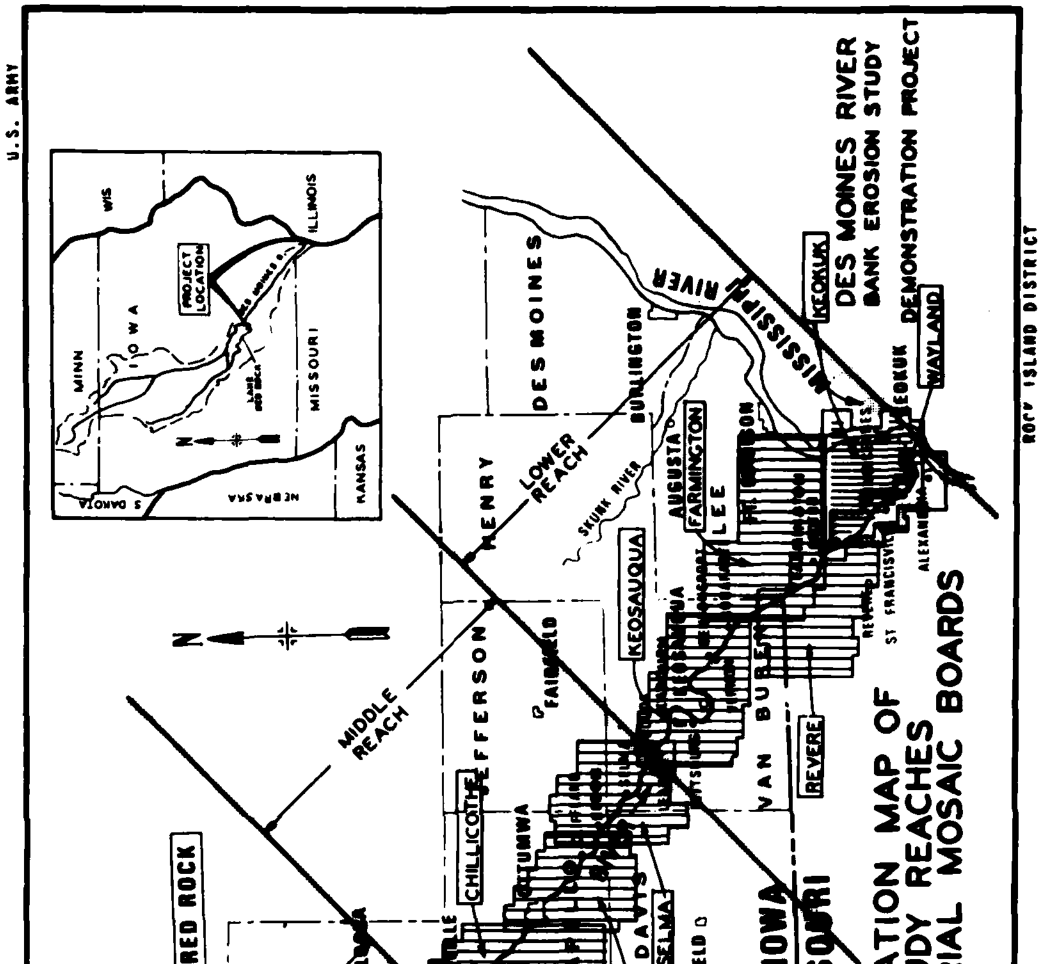

LOCATION MAP OF
STUDY REACHES
AND AERIAL MOSAIC BOARDS
DES MOINES RIVER
BANK EROSION STUDY
DEMONSTRATION PROJECT
LEGEND
SELMA - AREA COVERED BY AERIAL MOSAIC BOARD
CORPS OF ENGINEERS
U.S. ARMY
ROCK ISLAND DISTRICT
UPPER REACH
MIDDLE REACH
LOWER REACH
LAKE RED ROCK
BOARD 1
BOARD 2
CHILLICOTHE
OTTUMWA
SELMA
KEOSAUQUA
FARMINGTON
REVERE
KEOKUK
WAYLAND
POLK
DES MOINES
WARREN
INDIANOLA
JASPER
NEWTON
MARION
LUCAS
MONROE
MAHASKA
OSKALOOSA
APPANOOSE
CENTERVILLE
DAVIS
BLOOMFIELD
JEFFERSON
FAIRFIELD
HENRY
DES MOINES
BURLINGTON
LEE
VAN BUREN
AUGUSTA
SKUNK RIVER
MISSISSIPPI RIVER
IOWA
MISSOURI
OSCEOLA
CEDAR CREEK
ST FRANCISVILLE
MINN
WIS
IOWA
ILLINOIS
MISSOURI
NEBRASKA
KANSAS
S DAKOTA
PROJECT LOCATION

Figure 1

analysis also allows for an historical perspective in detail not available by any other means. This perspective can often be an important factor in project development.

GENERAL ANALYSIS

The analysis of the Des Moines River erosion allowed for preliminary judgments of many factors. The historical analysis helped identify that the river was flowing primarily over bedrock in a major segment of the 143-mile study area and no significant erosion had taken place during the 38-year study period. Several causes of erosion that had been theorized were also rejected due to the photo analysis. The historical vegetative and crop patterns indicated that certain areas could not be related to increased erosion. The erosion was not more severe opposite or immediately downstream from tributaries. Soil conditions and extreme flood flows had a significant impact on erosion as indicated by the variations in erosion in various soil types and based on the time period of the photo in relation to historic floods. This initial analysis indicated that the erosion process was not greatly different before and after completion of the Red Rock Dam. Theories based on crop patterns, land cover, strip mining, sedimentation from tributaries, and location of tributary junctions were able to be rejected as a result of the photo analysis. This, then allowed further studies to concentrate on river flows, soil conditions, and channel patterns.

On a broader basis, the interdisciplinary photo analysis provided a description of the area in fairly specific terms. Forest and habitat were described not only as they exist but as they developed over the past four decades. The growth and decline of urban areas, their relationship to the coal strip mining operations, manufacturing concentrations, transportation networks, and even to some extent, projections of future development were described. Agricultural production and recreation were also described in detail. Soil types and location of extractive operations were also identified.

CHANGES AND IMPACTS

Detailed study of the aerial mosaics over the 38-year period indicated that the river had established its meander patterns prior to the earliest photos that were studied. This was evident through old meander scars, channel changes, and oxbow lakes. In the lower reaches, the influence of the Mississippi River could be noticed.

Overlays were prepared to show comparative factors for each reach. The upper reach was determined to consist of shales over limestone with layers of sandstone and coal. There are extensive strip mining areas that were once active in this area; only a couple are still active. The extensive development of farm ponds in the area is indicative of erosive soils as are the conservation practices which have been developed to halt the upland erosion.

In the middle reach, shales and sandstone overlie limestone with the uplands overlain by glacial till and loess. The river flows extensively over rock; therefore, little erosion has taken place. Only about the upstream third of this reach has shown any significant channel changes. Forest cover has increased in this reach due to use for pasture, decreased cultivation of hillsides, and poor crop productivity.

The lower reach includes a large portion that is the Mississippi River flood plain. The erosion is influenced by the sandy soil conditions as well as Mississippi River levels. This is a very active meander area which has also been influenced by levee construction and a channel change made in connection with the construction.

Thus far, the analysis had resulted in a description of the areas involved and estimates of the patterns and magnitude of the erosion.

DETAILED ANALYSIS

Besides a descriptive process, the photo analysis had the best potential for the economic analysis, location of potential erosion control measures, and estimates of rate of erosion. Although the time period between photographs in this study did not allow for a comprehensive statistical analysis, this would be possible with more frequent coverage. Statistical procedures were still used to help verify data interpreted from the photographs and increase the reliability of the conclusions.

The photographs of the channel area for the 1975 base condition were enlarged to a scale of 1 inch = 400 feet and, with the use of a Zoom Transfer Scope, the channel area for the other time periods was plotted on a series of overlays. This procedure allowed for direct comparison of the channel changes as well as measurement of the rate of change. For the economic analysis, the various changes in land use were also plotted on the overlays. Not only were channel changes analyzed and measured, but the total impact of these changes was evaluated. In the case of the Des Moines River Erosion Study, the impacts were quantified to obtain the economic damage caused by the erosion process. A related analysis was also accomplished during this process. The width of the river at various locations and the length and radius of the curves were also measured.

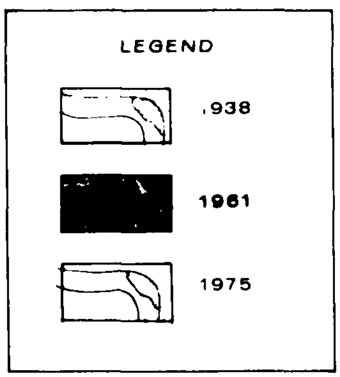
The channel change overlays were used to measure the rate of channel change and compare the various reaches with each other. This analysis showed that the rate of change varied by time period with the 1950-1969 period having the smallest rate of erosion. A check of flow records then showed that the erosion seemed to be related to peak flows since that period had an absence of high flows as compared with the preceding and subsequent periods. The flood of record occurred in 1947, and the photographs taken in 1950 showed evidence of substantial channel changes that had occurred only a short period prior to the photo. Some of these changes were so drastic that they could only be explained by a peak flow of great magnitude. The changes that had taken place during the 1969-1975 period, while greater than the 1950-1969 period, did not indicate drastic changes, but only a continuous erosion process. The 1969-1975 period was an unusually wet period, and although serious floods were prevented by the regulation of Red Rock Dam, average annual flows were greater. The wettest year on record was in 1973.

The land use changes as a result of the erosion served as the basis for economic evaluation. This procedure was accomplished in two phases. The first phase compared the 1975 with the 1938 photographs to determine the total amount of land lost during the period. This was accomplished by outlining the limits of the channel changes on overlays (Figure 2) and calculating the total land area within these limits for both years. The results of these calculations indicated that the net loss of land was not significant; i.e., less than 100 acres over the 38 years.

Erosion and accretion have a close relationship, and it was this association that was considered next. The 1:400 scale photographs were used to plot not only the channel location for the four time periods, but also the various broad land use categories (sand, crop, forest, and other). Losses and gains of each type of land were then measured on each photograph for each of the four years.

From a national economic point of view, a loss of land by erosion is offset by a similar gain in land by accretion. Although many individual landowners consistently had serious land losses, the development of National Economic Development benefits must also consider downstream land gains from accretion. The value of the land lost, however, is not the same as that accreted. The land eroded is generally productive land capable of some economic return. The land accreted has been sorted and dispersed in different areas. At some future time this accreted land will have a higher value, but the interim difference results in an economic loss.

As an example of the process that was interpreted from the photographs, cropland is eroded and subsequently deposited as a sandbar. The immediate result is a loss of cropland. However, as the sand lies in place and certain vegetation grows and silt is deposited, the newly created land can eventually become tillable again. The photographs allowed interpretation of this process and also estimates of the time frame necessary for this evolution to take place. Real estate appraisals were then applied to each type of land and an economic analysis completed (Figure 3).



DES MOINES RIVER BANK EROSION STUDY

DEMONSTRATION PROJECT

Figure 2

FIGURE 3

Total Area

Type	Acres Lost	$ Present Value Per Acre	$ Total Loss	Acres Gained	$ Discounted Value Per Acre	$ Total Gain
Crop	239	1,000	239,000	175	400	70,000
Woodland	796	250	199,000	784	140	109,800
Other	1,269	500	634,500	345	280	96,600
Sand	692	50	34,600	1,698	50	84,900
TOTAL	2,996		1,107,100	3,002		361,300

Net Economic Loss = $745,800
Emergency Costs = 206,000
Total Damage = $951,800
Annual Damage = $ 25,600
Feet of Significant Erosion = 110,500
Damage per linear foot = $ 0.23 $\frac{(25,700)}{(110,500)}$

The photo analysis as interpreted by an interdisciplinary team could not confirm that the rate of erosion varied significantly over the period of the analysis. Although the 1950-1969 period had lesser rates of erosion, the 1938-1950 and 1969-1975 periods had comparable rates.

SUMMARY

Based on the systematic interdisciplinary photo analysis, the erosion along the Des Moines River was identified as being caused by natural dynamic river processes. The economic damage was evaluated and used in the report to determine the feasibility of preventive measures. Through the use of the overall process, the description of the basin and a great deal of background information was obtained. The process documented data that could not have been obtained in any other manner that would have any degree of credibility. The program itself documented the value of the process and its applicability to a variety of uses. It also emphasized the importance of an interdisciplinary team.

Although this program was intended to demonstrate the broad application, its uses are being applied to a number of projects within the Rock Island District. These include the use for documentation in a court suit related to reservoir induced flooding, estimating crop losses due to flooding, flood area mapping, and obtaining data for the regulatory permit program.

The effort described used primarily black and white photographs. However, for many of the subsequent applications color infrared photography will also be used. The overall value of each type of film must be analyzed based on the specific requirements. The end result, however, is that a process of remote sensing by various means is available and its value can be enhanced by an interdisciplinary team effort.

ESTABLISHING A BASE LINE FOR ASSESSING MILITARY LAND USE IMPACTS TO ECOSYSTEMS WITHIN THE CHIHUAHUAN DESERT UTILIZING AERIAL PHOTOGRAPHY

KEVIN von FINGER

Environmental Office, DFAE
Fort Bliss, Texas

SUMMARY

Aerial stereo photoimagery was analyzed to provide a base line for assessing the ecological impacts of track vehicle maneuvers and ordnance caused range fires at a military installation located within the Chihuahuan Desert. Photos provided an excellent means of inventorying a biologically diverse area of over 3000 square kilometers in terms of delimiting discreet ecosystems and locating areas of high maneuver intensities for subsequent field investigation. Four environmental components were mapped on transparent overlays as a means of differentiating ecosystems; these included vegetation, soils, landforms, and drainage. Densities of vehicle tracks were mappable and provided a relative comparison of maneuver impact. Analysis of township survey records dating from 1858 to the present provided a means of mapping historic vegetation, soils, and topography as a gauge of pre-military ecosystem conditions.

INTRODUCTION

The study area is located in southern New Mexico and comprises about 3100 square kilometers of the Fort Bliss Military Reservation. Extending north 50 kilometers from the Texas-New Mexico border, the area includes the southern portion of the Tularosa Valley, a north-south trending interior draining basin, and the surrounding uplands bordering the basin to the east and west. Located within the Basin and Range physiographic Province, the area's diversity in elevation is considerable. Within the study area lie several mountain ranges or portions of mountain ranges. On the west of the basin, the igneous Organ Mountains reach a height of 2712 meters; on the east the primarily sedimentary Hueco Mountains rise to 1830 meters and blend softly into the Otero Mesa, a flat, uplifted plateau seperated from the basin by an escarpment up to 200 meters high. The foothills of the massive Sacramento Mountains border the northern portion of the study area. Basin low is 1190 meters.

A diversity of parent materials, slopes, and differences in precipitation result in a number of taxonomically different soil types. The basin soils are particularly diverse, derived both from alluvial fill from the surrounding highlands and eolian deposits possibly originating from extra basin fluvial transport during the Pleistocene (Pigott 1977).

Biologically and climatically the area is considered part of the northern Chihuahuan Desert (Shreve 1942; Blair 1950; Schmidt, in press). The basin averages about 20 centimeters annual precipitation, while higher elevations average considerably greater amounts, particularly where proximal mountain masses influence storm patterns. Floral and faunal diversity is high due to the variation in soils, precipitation, and evapotranspiration. The cooler north-facing canyon slopes of the Organ Mountains support Douglas fir (*Pseudotsuga menziesii*), while the basin supports variable component arid shrub associations within which are islands of grasslands. Otero Mesa receives approximately 50% more precipitation than the basin 200 meters below and is characterized as a grassland of differing species dominance than the grassland isolates of the basin.

Superimposed upon the biotic and abiotic components are a number of land uses associated with the military missions of Fort Bliss. There are two activities which appear to have considerable potential for disrupting or altering involved ecosystems. These include the maneuvering of tracked vehicles such as tanks, etc., and the firing of artillery and air defense weaponry, which can start range and forest fires upon surface impact. In order to comply with the mandates of the National Environmental Policy Act, Fort Bliss must assess the kind and degree of adverse impacts that may be occuring to the ecosystems resulting from these activities.

Impact analysis is a complex problem involving a number of factors common to military installations in general and particularly so to those in arid regions. Firstly, large land masses are involved, within which are diverse biotic and abiotic components comprising a large number of ecosystems. Each of these components, and therefore each ecosystem, may react differently to a given activity. It is therefore necessary to identify all the different ecosystems receiving the subject land uses and assess impacts individually within each. Secondly, impacts are related to intensity of maneuver and frequency and seasonality of fires. There are, however, no historic military records of activities which document either areas involved with maneuver use or fires, or their intensity, duration, frequency, etc. All basin areas that are topographically suitable for maneuver use have received such at some period during the past 30-40 years, although some areas may have received a much higher intensity than others; this is the case at present. A corollary of the ambiguity of historical data is that there are no control areas (so inherent to the scientific method) within the installation to compare with areas subject to the activities listed. Areas off the installation may be suitable as controls, although as distance increases between sites, so does the potential for climatic contamination of site data analysis. Precipitation has considerable random temporal and spatial variation within the basin.

Differences in precipitation can be as great as the annual average for sites separated by as little as ten kilometers (J. Williams, unpublished data). Stress observed in an ecosystem must be separated into two parts-that due to climatic (droughty) extremes, and that due to land uses. This can only be accomplished by a characterization of the relationships existing within each ecosystem. (The importance of field work to obtain the necessary base line data cannot be overstated. Lack of commitment to a long term in-depth analysis of ecosystem relationships will preclude successful impact analysis). A third complicating factor is pre-military land use, primarily cattle grazing. Overgrazing of the basin grasslands (if they indeed existed) beginning in the 1880's may have set in motion an irreversible ecosystem change (Buffington & Herbel 1965; York & Dick-Peddie 1969; Kenmotsu 1977) from grassland to mesquite (Prosopis) coppice duneland (although New Mexico township survey records suggest mesquite was present in abundance prior to ranching attempts within the basin). Elimination of grass cover would have permitted eolian transport of the soil into dunes. Current dynamics of the basin ecosystems, particularly soil redistribution and changes in floral composition, may be a residual of the stresses imposed by overgrazing. To analyze military impacts it will be necessary to elucidate background sources of apparent ecosystem instability attributable to climate and past land uses.

Aerial imagery analysis was deemed the most efficient tool to begin impact analysis for the following reasons.

1.) It was a cost effective means of inventorying a large area by providing a visual basis for defining and delimiting ecosystems; once ecosystems are identified, study plots can be established within each to obtain the base line data necessary to elucidate the relationships.

2.) The photos provided a relative visual comparison of extant maneuver damage within ecosystems by virtue of the densities of track patterns.

3.) The photos provided a permanent visual base line of ecosystem conditions and boundaries to which future comparison might be made to assess direction and degree of ecosystem change (which would of course be manifest as changes in ecosystem components such as soil redistribution, vegetative species composition, vegetative association boundaries, etc.).

4.) The photos provided a tentative basis for assessing degree and direction of ecosystem change due to pre-military land uses; this was accomplished by mapping an overlay of vegetation etc. as described in New Mexico township surveys, beginning in 1858.

TECHNICAL ASPECTS

The desired end product determines the type of imagery selected in a remote sensing application. In this study both color and black and white stereo imagery at a scale of 1:12000 were flown by aircraft. Overlapping stereo imagery was selected for its inherent advantage of portraying relationships of slope, topography, drainage patterns, and landforms.

Scale was chosen to provide sufficient detail of vegetation, vehicle tracks, and erosional features. As scale becomes smaller, a point is reached where such features (particularly vehicle tracks) become indistinguishable. Large scale limitations are imposed by the increase in time and funding required to analyze larger and more detailed photomosaics, and by virtue of the fact that, as the scale becomes larger, the relationships and boundaries between mappable units become obscured and accuracy in delineation of mappable units decreases. The scale of 1:12000 was selected as providing optimum mappability. Photo size reduction can be undertaken if necessary to reduce scale and provide a broader view of relationships over a larger area.

Color imagery can provide greater information than black and white, especially when mapping vegetation and soils. Black and white was flown as back-up imagery; however, due to excessive vignetting of the color, the black and white became the primary mapping imagery. Color provided back-up imagery for detailed mapping.

The individual photos were stapled to rigid 4 foot by 6 foot chipboard bases and the resulting photomosaics were overlayed with stable base mylar. Maps of environmental features were drawn upon the mylar by means of stereoscopic photo-examination. A separate mylar sheet was used for each mapping unit. Mapping was an interdisciplinary effort involving analysts in the fields of geology, engineering, geography, ecology, and soil science.

MAPPING UNITS

Four environmental features were selected as mapping units: vegetation, surficial drainage, land forms, and soils. These factors satisfied the basic criteria of being intrinsically identifiable and therefore mappable, and of reflecting the biotic and abiotic relationships of involved ecosystems.

VEGETATION

There are a great number of vegetation mapping schemes that can be applied to photoanalysis. The system selected depends in part upon the use of the final product - in this case ecosystem mapping and an aid to the identification of ecosystem relationships. The first step in mapping is deciding what vegetation information will be required and then devising mapping symbols for representation. A mapping system should reflect as accurately as possible the actual vegetative parameters existing on the ground. The mapping symbols must provide as much detail as necessary to render mappable a diversity of vegetation types, composition, and densities, yet not be unduly cumbersome. The system of mapping symbols should be sufficiently flexible to allow addition of new vegetative information (new species, etc.) as the project proceeds, while the symbols themselves should be brief and readily decipherable.

For this analysis, species composition and relative dominance of perennial vegetation was deemed most appropriate for discrete mapping units. Relative dominance was defined as relative species contribution to overall crown cover and was estimated visually from the photomosaics. While this method produces qualitative rather than quantitative data, its accuracy was validated by quantitative measure during field checking.

A three digit mapping system was devised, each digit of which represented one of the 3 most dominant species in that mapping unit, while the digits' position indicated order of relative dominance (first digit is more dominant than the second, etc.). There are exceptions to this scheme, since only nine digits are available for species assignment, and more than nine species were encountered as dominants. Bare ground and concentrations of annuals were also mapped. Therefore a coding system was devised, although it will not be discussed here; see Budd et al (1979) for a detailed discussion of the vegetative mapping scheme. A ground area of 2 hectares was set as the minimum mapping area (approximately 1.5 square centimeter on a photo).

LANDFORMS

Landforms were of four major types: mesa, bedrock (divided into igneous and sedimentary), alluvial, and eolian (dunes and sand fields). Alluvial and eolian types were subdivided into several units on the basis of 1.) relative topographic position, and distance from parent source for alluvial landform; 2.) topography, and photo pattern and texture for eolian landforms. The relative topographic position of alluvial units reflected relative age and stability of the units and surficial soils. High alluvial units were old fan remnants that escaped erosive action and whose surface soils are stable and well developed. Ten units of alluvial landforms and seven of eolian landforms were distinguished. In general, each unit was readily distinguished from another on the photomosaics. Due to the relatively few units, mapping symbolism was simple and that for each unit consisted of three letters from the name of the unit.

Landforms were selected as appropriate and informative environmental features in that they modify the macro and microenvironments by virtue of topography, slope, aspect, elevation, parent material, and drainage, and therefore aid in the delineation of ecosystems.

SOILS

Soils may be mapped from aerial photoimagery (see Morrison 1969; Pigott 1977) but considerable ground truth must be performed if they are to be accurately mapped as to taxonomic classification (Soil Survey Staff 1975). This is due to the fact that taxonomic catagories are based primarily upon subsurface horizon development, which is obviously not visible on the photos. Through ground truth, previously obtained soil data (Satterwhite, unpublished data), and the Soil Conservation Service (SCS) work in adjacent areas, it was possible to both correlate land forms with soils and soil mapping down to the subgroup level. The distinct advantage of taxonomic soil mapping is that it provides much more information for analyzing ecological relationships, in particular that of plant-soil-water. It further provides some information regarding the stability of ecosystems via the stability of the involved soils. Even if it were not feasible to map according to the taxonomic classifications, differences in color and sometimes texture of soils can be distinguished on the photos, although the level of separation of soils achieved usually will not be as high as with the taxonomic approach. In most areas of the country, the SCS has already mapped soils taxonomically from aerial phots, which can be used to generate a soils overlay.

DRAINAGE

There are no permanent streams or lakes within the study area due to the sparse rainfall. Ephemeral watercourses exist, however, and are obvious on the photos. They can be mapped by the presence of scoured channels in bedrock, broad, gravel filled incised channels on higher alluvial fans, and as wide, anastomosing washes at the toes of alluvial fans. No mapping symbols were necessary. Solid lines indicated incised channels, dotted lines and arrows the washes.

CULTURAL AND HISTORIC VEGETATION MAPPING UNITS

CULTURAL

A cultural overlay was produced to highlight surface evidence of vehicle passage. Vehicle tracks were visible over all slopes and terrain suitable for vehicle travel. Due to the restricted access into the installation, the great majority of, if not all, tracks represented military activity. The methodology employed to record tracks on an overlay was somewhat time consuming, but provided optimal track identification. All tracks visible with a stereoscope were traced on an overlay. When overlaid by a grid square, track densities can be quantitatively compared between ecosystems. Track densities varied considerably from ecosystem to ecosystem. Several interpretations could explain such differences; differences in maneuver intensities (steeper slopes had significantly fewer tracks); differential recovery of ecosystems; obliteration of tracks by shifting sands (particularly where sand fields are sparsely vegetated and sand redistribution is enhanced by soil cohesion loss caused by vehicle passes); differential response of soil and vegetation to vehicle passes. A portion of the basin has not been maneuvered in for at least three years, yet tracks are as obvious as in areas which are under daily use at present.

Considerable field work must accompany any analysis of track densities and persistance and how these relate to impacts upon an ecosystem. One approach would be the simulation of a range of maneuvering intensities within the various ecosystems during all seasons of the year. Impacts upon vegetation and soils and recovery rates could be measured. Comparison of differential track densities on the photomosaics would then be more meaningful and allow estimates of maneuver impact over large areas.

HISTORIC VEGETATION, LANDFORM, AND SOILS

New Mexico township survey records of the study area were sampled and evaluated to assess the feasibility of producing vegetative, landform, and soil maps reflecting pre-military occupation of the basin (and in some cases, pre-cattle ranching endeavors). It was felt that some conception of the magnitude and direction of ecosystem change might be ascertained. This in turn might provide a means to differentiate between military and non-military sources of stresses affecting the basin ecosystems over the past 100 years. Survey records date back as far as 1858, although there is considerable variation in descriptive detail. For example, the 1934 surveys mention only "typical desert vegetation." Other surveys were equivocal and the general summary of a townships' vegetation, etc., did not necessarily correspond with the more detailed descriptions for each of the 36 survey lines within that township. Ambiguous descriptive terminology of the early surveys often further confused the picture. Grass and soils were often simply described as first, second, third, or fourth rate, landforms as rolling,undulating, etc. It does not add to an interpreter's confidence when these terms are used in a number of surveys by different surveyors over several decades.

The general impression is that ecosystems have undergone some degree of alteration, and perhaps irreversibly so in some areas; since the late 1800's the scenario seems to suggest the presence of more or much more grass but no dunes, although mesquite was generally present, even common (today's unduned grass islands within the basin may indeed be relicts). A more inclusive evaluation of the remaining survey records, particularly if these were to be compared with later resurveys of the same townships, combined with a historical investigation of the temporal and spacial aspects of land uses, may well provide sufficient basis for separating the military, ranching, and climatic contributions to ecosystem stress.

FIELD PHASES

GROUND TRUTH

Ground truth (field checking) is necessary to verify the existance and accuracy of mapping unit boundaries observed on the photomosaics and to correctly label the bounded units. For the analyst, field checking provides an excellent means of developing an initial understanding of the [illegible]ical relationships within the study area. Ground truth should be performed after some mapping of unit boundaries has been completed, rather prior to or simultaneously with mapping, in order to optimize the re-[illegible] of visual differences on photomosaics by precluding bias or subjectivity in boundary delineation.

ECOSYSTEMS

The term ecosystem is used here broadly as defined in Odum (1959). The concept of ecosystem is based upon biological relationships at any of a number of different levels of analysis. In this study the level was determined by the scale of the photos and the visible differences in the selected mapping units. The resultant combination of bounded units provided analyzable entities which reflected biologically real systems on the ground.

After the landform, soil, and vegetation boundaries are drawn and the overlays combined, the ecosystems were in effect delineated. Drainage was not crucial for ecosystem bounding. This mapping unit did, however, significantly contribute to an understanding of why ecosystem boundaries existed. While elimination of this mapping unit would therefore not preclude delineation of ecosystems, its omission would seriously reduce knowledge of ecosystem component relationships.

ANALYSIS

Following ecosystem delineation, biotic and abiotic components within each ecosystem must be quantified through field study. Once component parts are so characterized, they can be monitored for any changes that might be brought about by military land uses. Component analysis may include, but not be limited to, floral and faunal species composition, population parameters, reproductive success, plant productivity and phenology, soil microbial flora and fauna, soil organic matter content, cohesion, permeability, water holding capacity, compaction, erosion, deposition, etc. Ecological relationships are enormously complex; a long term commitment to such analysis is mandatory for impact assessment. Profound and perhaps irreversible changes may be set in motion prior to any external manifestations of such changes. Continual monitoring of quantified ecosystem variables, however, may permit detection of symptoms of stress and change long before they become irreversible.

OTHER APPLICATIONS

The analyzed photoimagery can serve as an aid to installation master planning, and to environmental master planning in particular. For example, the imagery has aided technical and environmental planning and cut costs for the construction of an airstrip on Fort Bliss. The photomosaics permitted avoidance of both relict grasslands and the habitat favored by an endangered cactus, while helping locate topographically favorable sites for the airstrip and sources of caliche (an indurated calcium carbonate soil horizon) for strip surfacing. Archaeological and endangered species clearance surveys for the airstrip construction were made more efficient and therefore more cost effective by enlarging individual photos of the area to 1:3000 scale. The photo negatives were photo enlarged on engineering reproduction sheet film, and these in turn were the masters from which unlimited numbers of blueprint paper copies were produced for field use. Resolution was good and individual schrubs on the photo enlargement could be recognized in the field. These enlargements permitted location of a survey team's position while in the field and mapping of archaeological sites etc. in a virtually featureless desert expanse.

The imagery is being utilized to correlate categories of archaeological sites and site distribution with the biotic and abiotic features of the study area to attempt to elucidate mechanisms of prehistoric human adaptation to desert environments. The imagery may have registered previously unknown prehistoric sites; symmetrical patterns have been observed on the photos which do not appear to be military nor ranching in origin.

Endangered species management can similarly benefit from the photoimagery. For example, if a species' habitat requirements are sufficiently documented, likely areas for species survey can be located on the photomosaics, obviating time consuming ground demarcation of likely habitat. On Fort Bliss, the photoimagery will be utilized to locate colonies and estimate the population status of prarie dogs (*Cynomys ludovicianus arizonensis*), a state of New Mexico endangered species. The mounds thrown up around burrows are discernable on the photos. Since prarie dogs are the primary prey of the Federally endangered black-footed ferret (*Mustela nigripes*), locations of dog towns (and high population densities of other possible prey species such as the kangaroo rat, *Dipodomys*, whose mounds are also visible on the photos) will permit survey efforts for the ferret to concentrate in optimal prey density areas rather than spread over the entire 800 square kilometers of otherwise suitable habitat.

LIMITATIONS

There are limitations upon the photo analysis process that can be imposed by the quality of the imagery itself. The following is a list of potential deficiencies which could occur during the exposure of the imagery. If the imagery is to be obtained by contract, the contract should clearly stipulate the avoidance of these deficiencies.

1. Vignetting can obliterate the edges of a photograph, making it impossible to follow a feature from one photo to another on a photomosaic. Color is particularly susceptable to vignetting; the proper filter will eliminate this problem.
2. Insufficient side and end lap can prevent stereo viewing.
3. Scale changes (up to 30% have been observed) across individual photos interfere with stereo viewing and result in a mismatch of features (roads, unit boundaries, etc.) when photos are combined into a photomosaic. This can occur if the film plane is not parallel to the ground surface.
4. General lack of image sharpness and contrast can make it difficult to discern details or identify vegetation. This problem occurs as a result of light scattering due to airborn dust particles which reduces

resolution of surface features. This phenomena is prevalent in arid regions which have high ambient dust loads. As the air column heats up during the day, both turbulance and airborn dust increase. Photo missions should be flown in the morning hours, when possible, to avoid this problem.

5. Clouds can cast shadows which obscure detail and artifically create contrast. Flight scheduling should be flexible in order to minimize this problem.

6. Sharp differences in surface elevation along the flight path, if not taken into account and adjusted for, can create considerable scale change over the photomosaics.

LITERATURE CITED

BLAIR, W.F. 1950. The biotic provinces of Texas. Tex. J. Sci. 2(1):93-117.

BUDD, L.F., R.B. AREND, J.W. HURST and V.H. ANDERSON. 1979. Fort Bliss Environmental Analysis & Impact Assessment. Performed under Dept. of Army Contract #DAAK70-78-C-0151.

BUFFINGTON, L.C. and C.H. HERBAL. 1965. Vegetational changes on a semi-desert grassland range. Ecol. Monograph 35:139-164.

KENMOTSU, R.D. 1977. The botanical research. In: A Cultural Resource Inventory & Assessment of McGregor Guided Missile Range. Univ. Tex. at Austin. Res. Report #65, Part III:1-89.

MORAFKA, D.J. 1977. Is there a Chihuahuan Desert? A quantitative evaluation through a herpetological perspective. In: Transactions of the Symposium on the Biological Resource of the Chihuahuan Desert Region. R.H. Wauer & D.H. Riskind, ed. U.S. Dept. Int. Nat. Park Service transactions & proceedings series #3:437-454.

MORRISON, R.B. 1969. Photointerpretive mapping from space photographs of quaternary geomorphic features and soil associations in northern Chihuahua and adjoining New Mexico and Texas. The Border Region: New Mexico Geological Society Guidebook 20:116-130.

ODUM, E.P. 1959. Fundamentals of Ecology. W.B. Saunders Co., Philadelphia. 546 pp.

PIGOTT, J.D. 1977. Reconnaissance geology: implications for the analysis of human occupation. In: A Cultural Resource Inventory & Assessment of McGregor Guided Missile Range. Univ. Tex. at Austin Res. Report #65, Part III:95-153.

SCHMIDT, R.H. In press. Climatic delineation of the "real" Chihuahuan Desert. J of Arid Environments.

SHREVE, F. 1942. The desert vegetation of North America. Botanical Review 8:195-246.

STAFF, SOIL SURVEY. 1975. Soil Taxonomy. Soil Conservation Service, USDA, Agriculture Handbook #436. 754 pp.

YORK, J.C. and W.A. DICK-PEDDIE. 1969. Vegetation changes in southern New Mexico during the past hundred years. In: Arid Lands in Perspective. W.A. McGinnies & B.J. Goldman, ed. Univ. of Ariz. Press, Tuscon:155-166.

ACKNOWLEDGMENTS

Much of the photo analysis was performed by the Photographic Interpretation Corporation under Contract #DAAK70-78-C-0151. I wish to thank Lee Aikin of the U.S. Army Training and Doctrine Command and Colonels Ray Hansen and Joseph Rodriguez of Fort Bliss for administrative support; Bob Satterwhite of the Remote Sensing Division, Corps of Engineers Topographic Laboratories, for the use of his field data; and Robert Frost, Vern Anderson, Roger Arend, Lenore Budd, Jim Hurst, Bruce Buchanan, Sandy Dick-Peddie, and George Newbury for contributions to the photoanalysis.

DEVELOPMENT OF STAGE AREA TABLES FOR THE YAZOO BACKWATER AREA USING LANDSAT DATA

Franklin E. Hudson - Vicksburg Engineer District
Vicksburg, Mississippi

Dr. Horton Struve - Waterways Experiment Station
Vicksburg, Mississippi

ABSTRACT

This paper describes the development of stage-area relationships for portions of the Yazoo Backwater area in Mississippi utilizing Landsat digital data and digital topographic information.

---

1. PURPOSE

The purpose of this paper is to describe the development of stage-area relationships for portions of the Yazoo Backwater Area utilizing Landsat data and digital topographic information.

2. LOCATION

The Yazoo Backwater area is located in west-central Mississippi, within the delta area of the lower Mississippi River. The area under consideration is protected from Mississippi River flooding by the east bank Mississippi River levee and from backwater flooding by a backwater levee located along the west bank of the Yazoo River. This levee ties into the Mississippi River levee about 10 miles north of Vicksburg, Mississippi.

3. AREA AFFECTED

Within the Yazoo Backwater area under consideration which is protected from Mississippi River flooding are over 900,000 acres of delta land. All of this land is between elevation 75 and 107 ft, NGVD (National Geodetic Vertical Datum). Within the total area, all lands below elevation 100.3 ft NGVD remain subject to interior ponding during the

100-year frequency flood. The area slopes gently from north to south but is also broken by ridge and slough topography throughout. These ridges and sloughs result in finger-like projections at lower elevations in most areas.

4. NEED FOR AND USE OF DATA

The major immediate need for current relationships between flood elevation of ponded water and land area both cleared and wooded affected is for the evaluation of a system of flood protection including pumping plants. This evaluation principally concerns the effects of flooding on agricultural land and requires knowledge of up-to-date cleared land flooded at any given elevation. This information is also used for determination of baseline conditions from which land use changes can be evaluated, and is also used to determine flood damages in the area for any flood which may occur.

5. HISTORICALLY AVAILABLE INFORMATION

During the past 40 years several flood control projects have been evaluated in this area. In order to perform such evaluations, relationships of flooding to area affected were developed using aerial photography (5,000-10,000 ft). The cleared areas determined from such photographs were transferred to topographic maps (1:62,500) and the results planimetered within 5-ft contours. These results were graphically plotted to form a stage-area curve which shows total area and cleared area.

This procedure for development of stage area curves is costly in both dollars and man-hours expended. Such costs have resulted in not providing frequent up-dates of data.

Within this same area, there has been significant conversion of woodlands to cropland since the early 1960's. This trend is continuing, resulting in a need for frequent updating of cleared and wooded relationships at various flooding elevations at a reasonable cost, especially in man-hours expended.

6. USE OF LANDSAT DATA

As a result of the previously mentioned study of pumping plants in the Yazoo Area and the continuing need for up-to-date information for evaluation of flood damages, a decision was reached in mid-1978 to update the cleared/wooded-elevation relationships for over 900,000 acres of the Yazoo Backwater area. Recent increases in technological level and manpower shortages within the Vicksburg Engineer District were considered and it was decided to use Landsat digital data and digitized elevation contours to provide current information. Results were expected from this procedure within about 3 months for 8 individual stage-area curves.

Availability of historic manually planimetered total areas for various elevations provided for an easy check of total area at individual elevations. Those different land uses which could be easily determined from Landsat digital data were to be presented for all elevations within the study area. These land uses were to be cleared land, woodland, and water. A February 1978 scene (2110-15261) was selected to be used for these stage-area relationships.

7. PROBLEMS AND SOLUTIONS

The first run of data for stage area relationships for cleared land, woodland, and water for the over 900,000 acres was completed less than 90 days after initiation of work. This time period included development of computer programs, digitization of topography, and time lag for delivery of satellite data. (Detailed description of this work is discussed in Appendix A to this paper.)

When the results of this output were compared to historically available data, several problems were noted. These are discussed below:

a. The amount of permanent water reported was over 100 percent greater than previously planimetered.

b. Amounts of land at lower elevations (80.0, 85.0, and 90.0) exceeded previously planimetered amounts by more than 50 percent at some elevations. However, the total amount at the highest elevation considered was within less than 3 percent of the historic data.

Close examination of the February 1978 Landsat image showed that there were many areas of "water" which were questionable. A rapid field check of some of the areas in September 1978 was made. These areas were low-lying land with relatively poor drainage which had shallow water standing on them at the time of the February 1978 overflight but which were in row crops in September 1978. This substantiated the ability of the image to sort out areas including shallow water but not to separate these areas from permanent water areas. A Landsat scene (2264-15540) covering the total area which was made in October 1975 was available and was utilized for all subsequent information. An evaluation with this image resulted in total amounts of permanent water which closely approximated historic known information.

In order to evaluate areas flooded at critical elevations where the initial area output was significantly greater than that of historically known data, overlays of the area computed from the digitized topographic information were developed. These were compared with base topographic maps of the same area.

The first item noted in this comparison was that all pixels (100m × 100m) touching a contour line were computed as being at or below that elevation. Since the number of pixels on the finger-like conditions at the lower elevations in the ridge and slough areas was proportionally larger for the smaller areas at lower elevations, adjustment for this was considered necessary. This adjustment was made by computing the number of pixels touching each 5-ft contour line, determining the area in these pixels and reducing that area by 50 percent. This reduced the difference in planimetered and computed area at all elevation contours but a considerable difference, about 40 percent, still existed at elevation 85.0 and below. An immediate result of this adjustment was that the area computed for the 100, 105, and 110 contour lines was almost exactly within (1 percent in one instance) the historically computed areas. This was considered a verification of the need for such adjustment.

Modification of the computer program which summarized the number of pixels at or below any known contour was then considered. The program was changed to use the contour line and known points below (lower elevations) instead of the line and known points above (higher elevations) to compute the area at or below a given elevation. Results of this analysis when adjusted for border pixels were comparable to planimetered data at all elevations.

8. FINAL RESULTS

Summary of all eight individual curves which were developed as output from this work effort showed that the total areas were closely comparable (within 1-3 percent) to manually planimetered data. Previous studies have already confirmed satisfactory ability for determination of the major land uses (cleared land, woodland, and water) assigned by the computer to each pixel from Landsat images.

9. DISCUSSION AND CONCLUSIONS

Final delivery of data for use in economic evaluation for flood control studies occurred in mid-November 1978, about 1-1/2 months later than was originally anticipated. This time was utilized in developing solutions to the problems which have been previously discussed. A cost comparison of this work effort with the cost of providing the same data by traditional methods showed that the total cost of each method was about the same, approximately $30,000 for each method. However, two items must be considered in this comparison. The effort in man-hours required for traditional method would have been over two times that of the method utilized, even considering the time spent in developing solutions to problems. Also of prime consideration is that the topography of the area has been digitized and is stored so that costs of an update from Landsat digital data would be substantially less (estimated at about one-third the cost) while the traditional method would require the same effort as before.

The pixel size (100m × 100m or 2.47 acres) used in this effort is such that possibility for error in smaller areas might be greater. Use of a smaller pixel could also reduce the error potential for those pixels touching any individual contour line.

Care in selection of the Landsat data to preclude any unusual conditions which can exist in an individual scene such as the shallow water which was found on the February 1978 image can result in more immediate results without repetition of work effort.

While this work effort produced results that were satisfactory for use in any areas where an essentially flat water surface exists during flooding conditions, it was recognized that modifications to the computer program would be necessary for areas where water slope is a significant factor.

The total results of the work effort were adequate and this procedure can be utilized in the future to update land use conditions in this nearly 1500-square-mile area at costs substantially below traditional methods.

APPENDIX A: TECHNICAL DESCRIPTION

The approach used to develop stage-area relationships for the Yazoo Backwater area included four major tasks. The four tasks were: (1) to develop a gridded elevation data base; (2) to develop a land-use data base from Landsat Multispectral Scanner System (MSS) digital data; (3) to geometrically register data bases; and (4) to superimpose data bases and simulate flooding. A description of each of these tasks follows.

Elevation Data Base. Critical to the achievement of the objective of this study was the development of a gridded elevation data base. Conceptually, this type of data base can be thought of as a rectangular array of grid cells where each cell has been assigned an elevation value. A 100 × 100m cell size was selected for this study. A smaller cell size would have been preferred, but a trade-off between cell size and array size had to be made due to computer core limitations and cost. A nominal 300 × 300 array size was considered optimal for this study. To cover the study area, therefore, required nine such rectangular arrays.

Topographic data corresponding to each of the rectangular arrays was digitized, i.e., the elevation contours corresponding to each array were traced by a cursor and the position and elevation value of the contour points were recorded on magnetic tape. The digitized data were then submitted to a computer program that assigned to each grid cell an elevation value based on an interpolation procedure. The arrays were referenced to the Universal Transverse Mercator (UTM) Coordinate system, i.e., rows of the arrays were set parallel to the UTM Easting lines and normal to the UTM Northing lines.

Land-Use Data Base. Land-use data corresponding to each of the nine elevation arrays were obtained by classifying Landsat MSS digital data into one of the three land-use classes: woodland, cleared land, or water. The Landsat data was classified by using an iterative supervised procedure. The procedure required first that sample sets of signatures for each of the three classifications be extracted from the Landsat digital data. These sets were extracted as 3 × 3 arrays of Computer Compatible Tape (CCT) values and their average taken as the signature. The signatures were then subjected to a test of homogeneity. Signatures maintaining a standard deviation equal to or less than 1.5 CCT units in each of the four MSS bands were retained as valid representations of a given class while all others were rejected as nonhomogeneous or mixed pixels. The retained signatures were then tested for similarity and variance to obtain threshold values for classification criteria. If, after classifying the scene with the first set of threshold values, known areas were incorrectly classified, the original homogeneous set of signatures was enlarged. That is, signatures from the incorrectly classified areas were added to the original signatures and new threshold values obtained. This iterative procedure continued until a satisfactory classification of the scene had been obtained. Usually two iterations were all that were required.

Geometrical Registration. Registration of the land-use arrays to the elevation arrays was obtained for each array separately. The procedure, applied to accomplish the registration, first required that the Landsat pixel dimensions be accurately determined for each array. To do this, five uniformly distributed control points within or in the near vicinity of a given array were selected to be used as registration points or control points for that array. Corresponding locations of these control points were then determined within the Landsat data. By sightly varying the size of the Landsat pixel about its nominal size, the function F defined by

$$F = \left(\Delta D_1 + \Delta D_2 + \ldots + \Delta D_{10}\right)^{1/2}$$

could be minimized. The values of the ΔD's represent the difference in the distance between two control points as measured in the Landsat frame of reference and the distance as measured in the UTM frame of reference. For five control points, there exist only ten such differences. Once the minimum of F was found, the pixel dimensions corresponding to that minimum were taken as the pixel size for the given array. After the pixel size was determined, the remaining parameters necessary for registration such as flight path angle and the UTM coordinates of an origin (usually the first pixel of a scene) in the Landsat frame of reference could be readily determined. Using the proper registration parameters for each of the arrays, and resampling the Landsat data at 100-m intervals using the nearest neighbor concept, land-use arrays were extracted for each of the elevation arrays.

Simulate Flooding. To develop the stage-area relationships, the registered land-use arrays were superimposed onto the elevation arrays by a computer program that could simulate flooding conditions in a backwater area. Since the water surface in a backwater area experiences little slope (i.e. is nearly flat), the computer program simply determines which grid cells would be inundated for a given water stage. The program simulates flooding for all elevations within the area under consideration. The total area of woodland, cleared land, and permanent water inundated was then output to a printer for each elevation.

PROJECT-INDUCED LAND CLEARING
TENSAS RIVER PROJECT

Robert G. Wilcox - Vicksburg District, Corps of Engineers
Vicksburg, Mississippi

Dr. Horton Struve - Waterways Experiment Station
Vicksburg, Mississippi

ABSTRACT

This paper documents the Vicksburg District's use of aerial photography, Landsat digital data, and computer technology to prepare stage-area curves for use in economic analysis and develop a historical trend line analysis of the rate of land clearing activities with discrete flood zones for use in estimating project-induced land clearing.

This report documents a study conducted by the Corps of Engineers, Vicksburg District, using aerial photography and Landsat Multispectral Scanner System (MSS) digital data in conjunction with computer technology to provide an analysis of projected project-induced land clearing and stage-area relationships for the Tensas River Project (Phase I General Design Memorandum). The report provides background of the study, an explanation of project-induced land clearing and the problems it presents in a flood control project, and a detailed explanation of the methodology used in the study and the results obtained.

The Tensas River Basin is located in northeastern Louisiana, primarily in East Carroll, Madison, and Tensas Parishes, west of and adjacent to the Mississippi River. The basic authorization for the Tensas River Project was the Flood Control Act of 15 May 1928. Specific features of the Tensas River Project were authorized by the Flood Control Act of 1944. Channel improvements from river mile 0 to 160, including intermittent clearing, snagging, and excavation, were completed prior to 1949. The Flood Control Act of 1965 provided for an increase in channel capacity along the entire main stem channel and channel improvements along Mill Bayou and Bayou Vidal, a 17-mile tributary east of the Tensas River. The clearing and snagging from river mile 0 to 61 was completed in 1972 and allows the remaining improvements of the 1965 Act to be accomplished without causing any identifiable increase in flooding in the lower 61 miles of the Tensas River.

The Tensas Basin contains one of the largest remaining tracts of bottomland hardwood habitat in the Mississippi Valley (100,000 acres). These hardwoods are among the most productive wildlife habitat for game species; however, of the original 50 million acres of bottomland hardwoods, less than 1.6 million acres remain, mostly in tracts of less than 1000 acres.

At a public meeting in 1974, the Vicksburg District recommended a plan for the upper reaches which included five cutoffs and shortened the river by approximately 40 miles. Concerns over loss of bottomland hardwoods through direct rights-of-way clearing and project-induced clearing, as well as the possibility of induced flooding in the lower parishes, raised serious doubt as to the acceptability of this plan.

In 1977, the President asked Federal agencies to review the economic, environmental, and engineering (safety) aspects of a number of their water resources projects. The Tensas River Project was 1 of 19 Corps projects identified for this review. The Administration considered the major issue to be the proposed channelization of the Tensas River and the project impacts on bottomland hardwoods and endangered species or habitats. The President approved continued study efforts but recommended that channelization of the Tensas River be limited to the extent possible to avoid potential losses of bottomland hardwoods.

The need for flood control in the Tensas River Basin has been confirmed through study analysis, public input, and political support; however, it was decided that the original plan should be reconsidered in light of recent environmental legislation and policies to ensure that all resources in the basin were given proper consideration.

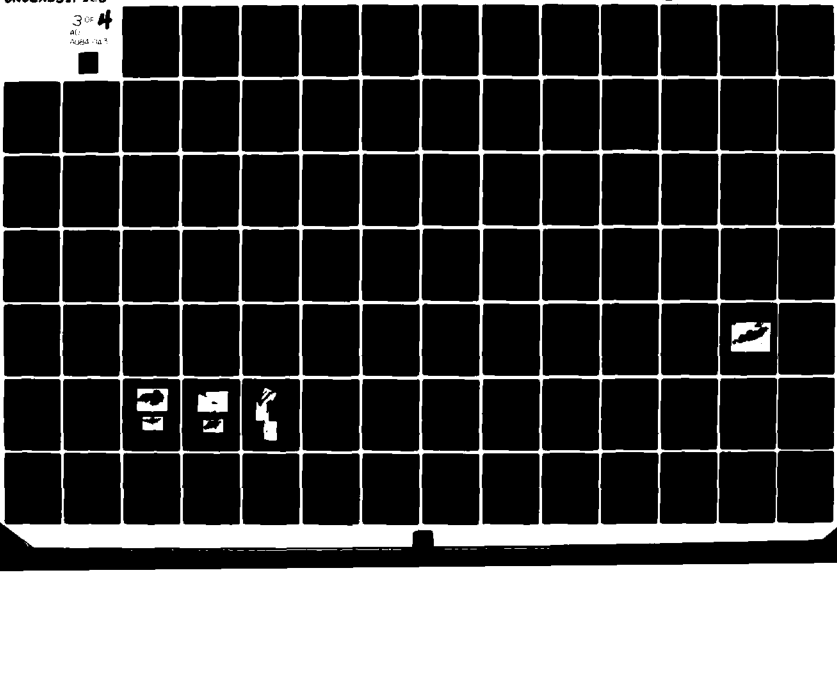
The losses of hardwoods which concern the Corps and Fish and Wildlife interests can be grouped into the general categories of direct losses and project-induced losses. Direct losses are those acreages lost due to channel excavation, dredged material disposal sites, and access rights-of-way. Project-induced losses are acreages which are cleared and placed in agricultural production in anticipation of or as a result of a reduction in flood damages due to a flood control project. Many wooded areas in the alluvial valley are generally too wet to support agriculture; however, a flood control project which reduced the duration and frequency of flooding in these areas could make it economically feasible to convert these areas to agriculture.

Direct losses generally are easily detected and analyzed. Induced losses, however, are speculative and usually have been analyzed through interviews with landowners. It is doubtful that the average farmer can accurately project his land clearing capabilities over a period of time

AD-A084 043 ARMY ENGINEER TOPOGRAPHIC LABS FORT BELVOIR VA F/G 17/8
U. S. ARMY CORPS OF ENGINEERS REMOTE SENSING SYMPOSIUM, 29 - 31--ETC(U)
OCT 79

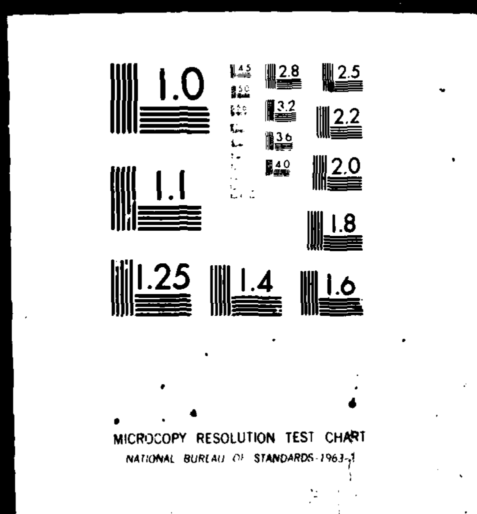
UNCLASSIFIED NL

3 OF 4
AD
A084 043



3 OF 4

AD
A084 043



long enough to be meaningful to an analysis of a project with a 50-year life. The Vicksburg District has been prompted to gather as much data as possible to analyze accurately the extent of project-induced land clearing.

The first step was to ascertain the historical relationship between flooding and land clearing. Using these data for discrete flood frequency zones, the historical trends could be projected through the planning period. These "without-project" trend lines could be adjusted to reflect "with-project" conditions. The differences between the without- and with-project trends indicated project-induced land clearing in time throughout the planning period. A technical description of the procedure used to develop land-use trends and stage-area relationships is provided in Appendix A.

Data concerning cropping patterns, land clearing costs, commodity prices, and land clearing trends were collected for East Carroll, Madison, and Tensas Parishes. These data were used to develop parishwide land-use trends and to investigate correlations between the various parameters and land clearing.

The lack of consistent and reliable land clearing data further encouraged the Vicksburg District to develop trends from the historical photographic record and the Landsat MSS digital data. Additional analyses which were also undertaken with the aid of the Landsat MSS data and the use of the computer included development of the stage-area relationships for 1978 existing conditions and delineation of flood zones for use in economic studies.

The evaluation of the historical data is not complete; however, several observations have been made in the development of the trend lines. The most notable of these are as follows:

a. Even if no Federal flood control project is implemented, most reaches will be cleared before the end of the project life unless action is taken to halt this trend.

b. There is little correlation between frequency of flooding and land clearing activities, i.e., more land has been cleared below the 1-year frequency zone than between the 50- and 25-year flood zones in some reaches. This indicates that even if a flood control project is implemented, there is no reason to assume that land clearing rates will increase, i.e., no project-induced clearing should be anticipated in this basin.

In summary, the Vicksburg District has used the MSS digital data in conjunction with computer technology to develop stage-area tables and maps indicating flood zones, tasks which formerly were accomplished primarily by hand. Past procedures were manpower-intensive and insufficiently flexible to allow detailed iterative evaluation of alternative plans.

The capability to analyze a flood control project with respect to its influence on land clearing is of significant value in light of current environmental concerns. Continued use of all available data concerning project impacts and development of new techniques will improve the accuracy of analysis.

APPENDIX A: TECHNICAL DESCRIPTION

The approach used to develop land-use trends and stage-area relationships in the Tensas River Basin included five major tasks: (1) develop land-use data bases, (2) develop a gridded elevation data base, (3) geometrically register data bases, (4) develop a computer model of the Tensas River, and (5) superimpose data bases and simulate flooding. Each of these tasks is described in the following paragraphs.

To develop the historical land-use trends in each of the three parishes of the Tensas River Basin, the years 1941, 1951, 1956, 1960, 1964, 1969, 1972, 1975, and 1978 were selected as data points along the time axis. These were chosen principally because data were readily available and the spacings between points were fairly uniform. Land-use data for the years prior to 1970 were obtained by photointerpreting aerial photographs; after 1970, data were obtained by classifying Landsat MSS digital data into one of three land-use classes: woodland, cleared land, and water. Land-use versus time curves for each of these classes were plotted for each of the three parishes. These curves were then subjected to correlation analysis with other data to establish cause and effect relationships.

The Landsat data were classified by using an iterative supervised procedure. First, sample sets of signatures for each of the three classifications were extracted from the Landsat digital data. These sets were extracted as 3 × 3 arrays of Computer Compatible Tape (CCT) values and their average was taken as the signature. The signatures were subjected to a test of homogeneity. Signatures maintaining a standard deviation equal to or less than 1.5 CCT units in each of the four MSS bands were retained as valid representations of a given class; all others were rejected as nonhomogeneous or mixed pixels. The retained signatures were tested for similarity and variance to obtain threshold values for classification criteria. If, after classifying the scene with the first set of threshold values, known areas were incorrectly classified, the original homogeneous set of signatures was enlarged. That is, signatures from the incorrectly classified areas were added to the original signatures and new threshold values obtained. This iterative procedure continued until a satisfactory classification of the scene had been obtained. Usually, only two iterations were required.

Critical to the development of stage-area relationships was the development of a gridded elevation data base. Conceptually, this type of data base can be thought of as a rectangular array of square grid cells where each cell has been assigned an elevation value. A 100 × 100m cell size was selected for this study. A smaller cell size would have been preferred, but a trade-off between cell size and array size was necessary because of computer core limitations and cost. A nominal 300 × 300 array size was considered optimal for this study. Eleven such rectangular arrays were needed to cover the study area.

Topographic data corresponding to each of the 11 rectangular arrays were digitized, i.e., the elevation contours corresponding to each array were traced by a cursor and the position and elevation value of the contour points were recorded on magnetic tape. The digitized data were then submitted to a computer program that assigned to each grid cell an elevation value based on an interpolation procedure. The arrays were referenced to the Universal Transverse Mercator (UTM) Coordinate system, i.e., rows of the arrays were set parallel to the UTM Easting lines and normal to the UTM Northing lines.

Land-use data corresponding to each of the 11 elevation arrays were obtained by extracting geometrically registered land-use arrays from the 1978 Landsat data. Registration of the land-use arrays to the elevation arrays was obtained for each array separately. The procedure to accomplish registration required that the Landsat pixel dimensions be accurately determine for each array. To do this, five uniformly distributed control points within or in the near vicinity of a given array were selected as registration or control points for that array. Corresponding locations of these control points were then determined within the Landsat data. By slightly varying the size of the Landsat pixel about its nominal size, the function F, defined by

$$F = \left(\Delta D_1 + \Delta D_2 + \ldots + \Delta D_{10}\right)^{1/2}$$

could be minimized. The values of the ΔD's represent the difference in the distance between two control points as measured in the Landsat frame of reference and the distances as measured in the UTM frame of reference. For five control points, there exist only ten such differences. Once the minimum of F was found, the pixel dimensions corresponding to that minimum were taken as the pixel size for the given array. After the pixel size was determined, the remaining parameters necessary for registration, such as flight path angle and the UTM coordinates of an origin (usually the first pixel of a scene) in the Landsat frame of reference, could be readily determined. Using the proper registration parameters for each of the arrays and resampling the Landsat data at 100-m intervals using the nearest neighbor concept, land-use arrays were extracted for each of the 11 elevation arrays.

Also, essential to the preparation of the stage-area relationships was the development of a computer model that could represent the surface of the Tensas River at any point along the stream's length for any given stage. From historical and extrapolated stage data, a set of river profiles for the 1-, 2-, 3-, 5-, 10-, 25-, 50-, 100-, and 500-year frequency floods were generated. These profiles were programmed into the computer as straight-line segments from gage to gage. The stages between any two frequency floods were linearly interpolated for any given point upstream or downstream. Thus, the computer subroutine as programmed could calculate, for any given coordinate along the stream, the elevation of the floodwater's surface.

To generate the stage-area relationships, the registered land-use arrays were superimposed onto the elevation arrays by a computer program that incorporated the subroutine that modeled the water surface of the river for any given flood stage. Since the Tensas River runs generally north to south (i.e. slopes from north to south), the rows of the land-use and elevation data arrays were nearly perpendicular to the river. Thus, to simulate flooding in the simplest fashion, the program would search along a given row and determine which grid cells should be inundated. If the elevation of the river was higher than any grid cell along that row, the computer program designated that cell as being inundated. After examining the first row of elevation values on the north side of an array, the program would proceed southward to the next row and repeat the analysis with a new elevation value for the river. This process continued until all rows had been examined and all inundated cells tagged. The total area of woodland, cleared land, and permanent water associated with the inundated cells for a given stage of the river could then be easily summed and stored in the computer. The program simulated flooding in this way for each 0.1-ft increase of the river stage beginning at 0-ft flood stage and ending at the 500-year frequency flood stage. At the end of a computer run, a table of river stages versus areas of inundated woodland, cleared land, and permanent water was output to a printer and a card punch. Maps showing the extent of the flooding for the 2-, 5-, 25-, and 500-year frequency floods were also produced by plotting a boundary around the tagged grid cells associated with each of these flood stages.

USE OF AERIAL PHOTOS TO ANALYZE ALTERNATIVE FUTURES AND TO IDENTIFY SENSITIVE ENVIRONMENTAL SITES IN EARLY PLANNING

SUSAN BAILEY

U.S. Army Corps of Engineers
Portland District
Portland, Oregon

ABSTRACT

Information on future population distributions and on the physical environment of the study area are needed for planning. In the Portland Urban Study, aerial photographs were used to obtain the needed information and to explain its implications.

In the Portland-Vancouver Urban Study, photo-interpretation was used to prepare working maps for environmental assessment and to evaluate alternative futures (land use and population distribution). Both analyses used combinations of U-2 high altitude false color infra-red imagery (about 1:32,500), black and white ortho-photo-quads (1:24,000), and U.S.G.S. topo maps (1:24,000). Both sets of analyses incorporated supplementary information available from local experts and existing reports and plans. The U-2 imagery, because of its scale and because it was in color, allowed the researcher to both keep a regional perspective and, at the same time, focus quickly on important features. The ortho-photo-quads provided a base from which accurate measurements could be obtained, and because of their larger scale, more detailed land-use and vegetation analysis could be performed. The two analyses provided basic land-use and habitat information which was used throughout the studies. Because the data were based on photographs, which any individual could quickly examine if he or she questioned the results of the assessments, public understanding and acceptance of the projections used (especially for land use, a sensitive issue) was increased. The photographs were invaluable as a planning tool because problem areas and surrounding conditions could be identified quickly, and many interrelationships were immediately apparent.

In the Portland Study, students were hired to perform the analyses because the primary study encompassed several hundred square miles and was a complex study area. The techniques used, however, can be applied by anyone having a small project and budget, and rudimentary photo interpretation skills.

ANALYSIS OF LINEAR FEATURES ASSOCIATED WITH CORPS PROJECTS

S. Holmes, R.K. Dodge
U.S. Army Corps of Engineers-Portland District
Portland, OR

ABSTRACT

Analysis of linear features was conducted for Geology Section. This project is still underway, however, evaluation of those lineaments detectable on Landsat (MSS) imagery has been completed.

Analysis of lineaments found on high altitude imagery (i.e., Landsat, NASA U-2) can be of great value in determining the seismic characteristics in the area of Corps projects. Similarities between trends and locations of many Landsat-detected linear features and known faults support the assumption that some linear features and linear systems are geologically controlled. Some of the geomorphic features that may have a linear aspect are alignment of; stream or stream segments, offsets along adjacent streams, ends of consecutive ridge spurs, groups of anomalous topographic features (such as continuous straight ridge crests aligned with straight reaches of streams), tributaries, saddles and others.

Not all linear features are geologically controlled, however. Many cultural features create apparent lineaments. Railroads and highways are the most prevalent of linear cultural features but not the only ones.

Linear and curvilinear features were located on 1:500,000 Landsat images. The images used are color composite computer enhanced products developed by the EROS Data Center. These images were studied on a variable intensity light table and a smaller portable light table. Observed lineaments were copied on to semi-opaque vellum overlays. Each scene was studied separately and in conjunction with others. Because of the variations in scene location and the times scenes were imaged, lineaments observable in one scene may or may not be visible in overlapping portions of adjacent scenes. This multiple scene analysis allows examination of a maximum number of lineaments.

AERIAL PHOTO ANALYSIS IN SUPPORT OF SECTION 10/404 RESPONSIBILITIES

R.K. Dodge, S. Holmes
U.S. Army Corps of Engineers-Portland District
Portland, OR

ABSTRACT

Regulatory Functions has an on-going program of inspecting waterways and wetlands with current photography. The Warrenton Lumber Company litigation is used as a specific example.

The basis for the U.S. Army Corps of Engineers' reponsibility to regulate the disposal of dredged or fill material is the Federal Water Pollution Control Act Admendments of 1972. Section 404 of that Act charges the Secretary of the Army, acting through the Chief of Engineers, to regulate the discharge of dredged or fill material in the waters of the United States.

Along with the discharge of material which has been dredged or excavated from any waters of the United States, the following additional types of activities are also regulated by this program and through Section 10 of the Rivers and Harbors Act of 1899: Site developmental fills for recreational, industrial, commercial, residential and other uses; causeways or roadfills; dams and dikes; artificial islands; property protection and/or reclamation devices such as riprap, groins, seawalls, bulkheads and fills and breakwaters; beach nourishment; levees; sanitary landfills and backfills required for the placement of structures such as sewage treatment facilities.

Determination of changes in any and all of these activities can be accomplished quite easily through comparison of pre-existing photography with recent photography. Areas of recognized change can then be checked by a field inspection. This procedure will eliminate the need for the inspector to go into areas of difficult accessibility and/or areas without any significant activity.

Portland District is utilizing a number of photographic formats and scales for this purpose (i.e., black and white 1:12,000, 1:24,000 and 1:36,000; color film 1:24,000 and 1:36,000; and color infra-red 1:24,000. Color infra-red film at 1:24,000 has proven to be most effective in this task.

SEDIMENT DEPOSITION PATTERNS IN SAN FRANCISCO BAY

John F. Sustar

U.S. Army Engineer District
San Francisco, California

The thrill and commitment of space age platforms opened the thoughts of many real and unreal applications of remote sensing to every aspect of earth sciences. Sedimentation in an estuarine system was no exception. Numerous application studies have been undertaken to quantify sedimentation patterns using ground truth and differences in image density. Two studies addressed sediment circulation in the northern portion of San Francisco Bay. The objective of these studies was to determine the extent to which imagery could be used to understand sediment circulation and deposition patterns.

San Francisco Bay is a bifurcated system. The Bay is generally shallow with two-thirds of the area less than 18 feet deep. The mean tide range is about 5 feet. At mean lower low water, about 64 square miles of mudflats are exposed. The major freshwater inflow which is highly seasonal flows through the northern portion from the Sierras and the Central Valley. The estuarine system consists of several successive bays connected by restricted straits.

Mare Island Naval Shipyard is at the upper end of San Pablo Bay about 30 nautical miles from the Golden Gate. The average annual dredging necessary to maintain the service channel (Mare Island Strait) is about 2.5 million cubic yards. Sedimentation occurs during the high discharges from the Delta in the winter and with the wind-wave and tidal recirculation within the Bay during the remainder of the year. Within Mare Island Strait, pre- and post-dredging surveys provide an insight into the sedimentation patterns on both a temporal and spatial basis. Sediments dredged from Mare Island Strait are released in Carquinez Strait downstream of Mare Island Strait. The effectiveness and the impact of this release of fine sediments (50-70% clays) were investigated using neutron activation techniques to quantitatively trace the sediment movement over a one-year period. In addition to the tracer program, historical deposition/erosion patterns were analyzed in San Pablo Bay.

In Mare Island Strait, a test program of dye releases was monitored using color film. Additional information included current measurements and suspended solids analysis. In San Pablo Bay, the results of the tracer program were compared with Skylab, Landsat and lower elevation imagery.

In San Pablo Bay, no correlation between the results of the tracer program and the density of the imagery could be determined. Sediment circulation patterns are related to the progressive changes in hydrodynamic forces which are not reflected in instantaneous time elements of imagery. The imagery can be used to evaluate local eddying conditions which may contribute to but not necessarily control sedimentation.

In Mare Island Strait, the dye studies indicated a cross channel current on the surface. This information combined with current data through the water column and compared with the deposition pattern indicates a helical flow pattern in the strait.

With the environment of San Francisco Bay, remote imagery provides only surface information. The only phenomena which can be interpreted with remote imagery are those which directly effect and/or are affected by surface characteristics. Remote imagery can only be used as a tool in setting up field studies and in evaluating field data to gain an insight into understanding sedimentation processes.

USE OF PHOTOGRAMMETRY
FOR
CADASTRAL AND BOUNDARY SURVEYS

John P. Erlandson
Chief, Survey Branch, Seattle District
Seattle, Washington

ABSTRACT

In 1975, the Survey Branch, Seattle District, was assigned the task of locating and establishing the guide taking line for the Chief Joseph Dam and Reservoir Project. The reservoir is about 60 miles long and located on the Columbia River, in a remote and generally inaccessible area of the State of Washington. Because of project size, absence of canopy and rugged terrain, photogrammetry was selected as the most cost effective method to; (1) assist the land surveyor in locating existing section and quarter corners; (2) aid in restoration of lost corners, and (3) use as a means for determining State Plane Coordinates of all corners. The work was accomplished in four phases. Phase 1 included cadastral retracement and installation of photo targets on found corners and in vicinity of unfound corners. Phase 2 involved acquisition of aerial photography and determination of target coordinates by photogrammetric procedures. Phase 3 involved restoration of unfound corners, and Phase 4, the establishment of the taking or boundary line.

LANDSAT AND THE NATIONAL DAM SAFETY PROGRAM IN ILLINOIS

Raymond R. Dumas, Civil Engineer
U. S. Army Engineer District, Chicago
Chicago, Illinois

Andrew R. Blystra, Civil Engineer
U. S. Army Engineer District, Chicago
Chicago, Illinois

ABSTRACT

This paper describes the use of LANDSAT in updating and verifying the inventory of dams in Illinois. The inventory is part of the National Dam Safety Program. The paper describes current procedures and gives the results of the program for approximately 60 percent of Illinois.

1. INTRODUCTION

The purpose of this presentation is to give background information about the National Dam Safety Program and the use of LANDSAT in this program.

The current work being done in inventorying and inspecting done throughout the United States was authorized by Public Law 92-367, dated 8 August 1972. The present work consists of updating and verifying the 1975 inventory data. The Chicago District is responsible for execution of the program in Illinois.

LANDSAT is being used to identify and locate dams for the inventory. The objective of using LANDSAT is to provide a uniform, nationwide method to help insure that all dams subject to PL 92-367 are properly identified and are included in the National Inventory of Dams.

2. DISCUSSION

Dams to be included in the inventory are all artificial barriers which impound or divert water and are 25 feet or more in height or have an impounding capacity at maximum water storage elevation of 50 acre-feet or more. Excluded are barriers which are six feet or less in height, regardless of storage capacity, or barriers which have a maximum storage capacity of 15 acre-feet or less, regardless of height. Therefore, a dam 26 feet high impounding a maximum of 16 acre-feet of water would be included in the inventory.

All possible sources of information and data are used to obtain information about existing dams. Location and identification of dams are obtained from available sources such as LANDSAT map overlays, U.S.G.S. Quadrangle map sheets, floodplain maps, U. S. Register of Dams, State and County highway maps, U. S. Department of Agriculture, Soil Conservation Service, Illinois Department of Transportation permit file, Illinois State Water Survey, contacts with owners, and field visits to dams.

The inventory update and verification in Illinois is being performed by the Chicago District with assistance from a consulting engineering firm. The Chicago District obtains and assembles the LANDSAT map overlays and then transmits these overlays to the consultant. These overlays are at the same scale as available U.S.G.S. Quadrangle maps. The consultant then uses the LANDSAT map overlays in conjunction with the U.S.G.S. Quadrangle maps and 1975 inventory data as a first step to identify and locate bodies of water and dams. After the consultant has used LANDSAT and other available sources to locate dams which may meet the required size criteria field visits are made to determine if the dam qualifies for the inventory and to obtain pertinent information about the dam. Then the consultant assembles the required data for each qualifying dam and transmits the data to the District for inclusion in the inventory. As of September 1979, the inventory had been verified and updated for approximately 60 percent of Illinois. Inventory work will be completed in Illinois by August 1980.

The 1975 inventory contained 928 qualifying dams for Illinois. In Fiscal Year 1978 inventory work consisted of updating and verifying data for those dams located in the southern 23 counties of Illinois. Table 1 shows the results of the work performed during 1978

	Number of Dams
Dams in 1975 Inventory	239
Deletion of Nonqualifying Dams	-76
Addition of New Qualifying Dams	+33
Total Dams, 1978 Inventory	196

Table 1. Results of 1978 Inventory, Southern 23 Counties

An analysis of LANDSAT used for the southern 23 counties showed that 39 of the 196 qualifying dams and reservoirs were not detected by LANDSAT. Results also showed that 12 qualifying dams and reservoirs were detected by LANDSAT but were not detected by any other method.

LANDSAT generally is capable of identifying bodies of water having a surface area of 10 acres or more. However, a 26-foot high dam impounding 16 acre-feet of water could have a reservoir surface area of only four or five acres. It appears that the qualifying dams not identified by LANDSAT in 1978 inventory work were usually the small size reservoirs.

In an attempt to identify more qualifying impoundments, LANDSAT was modified so that approximately 50 percent of the map overlays used in the Fiscal Year 1979 work included new features. The original spectral limits identified only those pixels whose surface was 100 percent water. This was modified so that pixels spectrally similar to water are mapped but are identified with different symbols than those used for 100 percent water. For example, if 20 percent of a pixel was identified as water, a symbol representing 20 percent water would be mapped.

During Fiscal Year 1979, inventory work was completed for the dams in the central 35 counties of Illinois. Results of the 1979 work is shown in Table 2.

	Number of Dams
Dams in 1975 Inventory	353
Deletion of Nonqualifying Dams	-116
Addition of New Qualifying Dams	+88
Total Dams, 1979 Inventory	325

Table 2. Results of 1979 Inventory, Central 35 Counties

An analysis of the capability of the revised LANDSAT to identify qualifying dams is in the process of being made. However, as work progressed during 1979, it was apparent that LANDSAT was not identifying all qualifying dams and reservoirs. A check of two counties revealed that all sources of data were missing some of the smaller dams which qualified. As a result, aerial photographs were added as a source of possible information.

3. CONCLUSION

The Chicago District experience has been that LANDSAT is a valuable tool in updating and verifying the inventory. However, the major shortcoming of LANDSAT is its inability to identify the smaller dams and reservoirs. Therefore, at the present time, LANDSAT must be used in conjunction with other sources of data to verify and update the inventory of dams.

VERIFICATION AND UPDATING THE NATIONAL INVENTORY OF DAMS USING LANDSAT

Jim Cook
Civil Engineering Tech, Nashville District
Nashville, Tennessee

Kenneth Graybeal
Cartographic Tech, Seattle District
Seattle, Washington

ABSTRACT

The National Aeronautics and Space Administration (NASA) has developed at the request of the Corps of Engineers, a computer-aided procedure called the Detection and Mapping (DAM) package, for locating and mapping surface water from Landsat data. The Nashville and Seattle Districts, acting as regional processing centers, are currently using this procedure to prepare computer maps of the United States, in support of the National Dam Safety Program. These maps are being used by district personnel, responsible for executing the inventory, as a tool to help insure that all dams subject to Public Law 92-367, are properly located and identified on the inventory. The mapping program, which began in May 1978, is being accomplished by the centers using computers located in Austin, Texas and Richland, Washington. Over 100,000 maps at a scale of 1:24,000 will be processed by the time the program is completed in December 1979.

DETERMINATION OF LAND USE FROM SATELLITE IMAGERY FOR USE IN HYDROLOGIC MODELS

ARLEN D. FELDMAN
ROBERT J. CERMAK

The Hydrologic Engineering Center
U.S. Army Corps of Engineers
Davis, California

POSTER PRESENTATION SUMMARY

This poster display presented the Hydrologic Engineering Center's (HEC) experience with: (1) using a LANDSAT land use classification procedure and (2) comparing the hydrologic results obtained from the alternative determinations of land use. The land use/cover identification methodology utilizing LANDSAT imagery was applied to six watersheds across the U.S. The land use information, stored in a grid cell data bank, was the basis for determination of hydrologic parameters for watershed models. Flood frequency studies were completed on three of the watersheds. The flood frequencies were obtained using the HEC-1 (Hydrologic Engineering Center, 1978) watershed model with runoff parameters derived from land use obtained from both LANDSAT and conventional low altitude aerial photography.

HEC has been involved in a NASA ASVT project entitled "Water Management and Control" (Hydrologic Engineering Center, 1979) which tests and evaluates a procedure developed at the University of California, Davis (UCD) for determining land use/cover from LANDSAT imagery. The UCD procedure (Algazi, 1979) was designed with the objective of providing Corps of Engineers' District offices with an operational cost-effective alternative to conventional methods of obtaining land use data. A constraint on the procedure was that it requires neither special remote sensing expertise nor expensive image processing equipment beyond what would normally be available to the field office; i.e. line printer, card reader, remote terminal, and access to a general purpose computer. The UCD procedure consists of an intergrated set of computer programs centered around an unsupervised classification routine. Data quality check, geometric registration and correction, data classification, symbol map generation, resampling and masking are all accomplished without the use of an interactive color image display.

The UCD classification technique was applied primarily to sites where Corps' Expanded Flood Plain Information (XFPI) studies (Davis, 1978) were underway. The XFPI studies were chosen because land use classifications by conventional methods were already entered into grid cell data banks for use by hydrologic models. Thus, after the LANDSAT land use classifications were made and entered into the grid cell data bank, the hydrologic analyses could easily be rerun with the LANDSAT land use as the basis for the hydrologic parameters.

HEC has applied the UCD classification method to Crow Creek near Davenport, Iowa and Walnut Creek near Austin, Texas. Available ground truth data permitted the identification of seven land cover categories from LANDSAT imagery: agricultural, residential/highways, industrial/commercial, grassland, forest, undeveloped open space, and water. Hydrologic simulations of three additional watersheds, previously classified by UCD staff during the development of the procedure, were made using both conventional and LANDSAT land use data. Resulting discharge frequency curves were compared to determine the effectiveness of LANDSAT land use in estimating "true" land use for hydrologic modeling purposes. The results of HEC's land use classification for Walnut Creek and the hydrologic analysis of Pennypack Creek near Philadelphia, Pennsylvania were described by Cermak, Feldman, and Webb, 1979.

Based on HEC's experience with the UCD procedure and LANDSAT imagery, the land use classified by that means appears to be adequate for hydrologic modeling purposes. The flood frequency curves derived from watershed model parameters using LANDSAT and conventional land uses were not significantly different.

References

Hydrologic Engineering Center, 1978. "Flood Hydrograph Package (HEC-1)." U.S. Army Corps of Engineers, Davis, California.

Hydrologic Engineering Center, 1979. "HEC/UCD/NASA Water Management and Control ASVT: Final Report." U.S. Army Corps of Engineers, Davis, California.

Algazi, V.R., G.E., Ford, and D.I. Meyer, 1979. A Non-Interactive Approach to Land Use Determination. 1979 Machine Processing of Remotely Sensed Data Symposium, Purdue University, June 27-29.

Davis, D.W., 1978. Comprehensive Flood Plain Studies Using Spatial Data Management Techniques. Water Resources Bulletin 14(3): 587-604.

Cermak, R.J., A.D. Feldman, and R.P. Webb, 1979. Hydrologic Land Use Classification Using LANDSAT, Proceedings AWRA Fifth Annual William T. Pecora Memorial Symposium," Satellite Hydrology." Sioux Falls, South Dakota, June 1979 (reprints: Hydrologic Engineering Center Technical Paper No. 67, 1979).

MONITORING STRUCTURAL DISPLACEMENT BY PHOTOGRAMMETRIC METHODS

Kenneth Graybeal
Cartographic Tech, Seattle District
Seattle, Washington

ABSTRACT

For the past six years, the Seattle District, Corps of Engineers, has been using photogrammetric methods to monitor structural displacement. The method and computational process developed by the district, can be a cost effective alternative to conventional field surveys for measuring structures, such as bridges, buildings, dams, and slide areas. The system consists of photographing structures at periodic intervals, using either terrestrial or aerial photography and measuring the photo image coordinates of permanently installed targets. The coordinates of the targets are determined by a least square computational process, then compared to the previous or base measurement for relative displacement. Measurement accuracies in the neighborhood of 1 part in 50,000 are being achieved on a routine basis for three projects presently under surveillance.

CORPS OF ENGINEERS SNOW COVER MAPPING IN NORTHERN MAINE USING LANDSAT DIGITAL PROCESSING TECHNIQUES

Carolyn J. Merry[1]
Harlan L. McKim
Roy E. Bates
Stephen G. Ungar[2]
Saul Cooper[3]
John M. Power[4]

ABSTRACT

The objective of this study is to map snow cover/vegetation relationships from Landsat digital data for indirectly determining the water equivalent of snow. If a general relationship is identified, the correlation of water equivalent in the snowpack with multispectral signatures developed from the Landsat computer compatible tapes (CCTs) will reduce the amount of ground truth required in estimating the amount of spring water runoff.

The study site selected was the Upper Saint John River Basin in northern Maine. During October 1977, 11 snow courses were established based on vegetative type, slope, aspect and elevation. The sites were selected primarily based on four vegetation classes: mixed, hardwoods, softwoods and cleared land. For each vegetation type a selection was made, when possible, of various elevations (from 600 to 1,500 feet) and aspect (north, south, east and west), within a five-mile radius of Allagash, Maine.

A meteorological station was installed at Allagash, Maine to obtain data on local climatic conditions. The instrumentation includes a rain

[1]Geologist, Research Soil Scientist and Meteorologist, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire 03755

[2]Director, Earth Resources Program, NASA Goddard Institute for Space Studies, New York, New York 10025.

[3]Chief, Water Control Branch, New England Division, Corps of Engineers, Waltham, Massachusetts 02154.

[4]Senior Hydrologist, Environment Canada, Ottawa, Ontario, Canada K1A 0E7.

gauge, maximum and minimum thermometers, hygrothermograph, and a wind passage instrument. Also, a Landsat data collection platform has been installed at one of the snow course sites for measurements of air and ground temperatures, and wind passage.

Measurements of snow depth and water equivalent have been obtained at the 11 snow courses in conjunction with the Landsat-2 and -3 imagery acquisition for the past two winter seasons. In addition, snow pit studies were conducted at three of the 11 sites to characterize snow properties. Weekly snow course measurements and snow pit studies were performed at the site of the meteorological station. Relatively cloudfree Landsat digital data have been obtained for: 20 December 1977, 7 January 1978, 12 February 1978, 2 and 20 March 1978, 31 May 1978, 24 December 1978 and 11 January 1979. A Landsat CCT dated 27 October 1977 was used to establish baseline conditions of the study area before any accumulation of snow.

Each standard Landsat CCT is computer-processed to produce a geometrically corrected tape with the Landsat pixels transformed to a UTM (Universal Transverse Mercator) projection. This results in a 1:24,000 scale computer map printout. The GISS (Goddard Institute for Space Studies) computer algorithm allows for supervised, unsupervised, time history or unfanning computer classifications of the Landsat digital data.

Each Landsat pixel is considered as a vector in a four-dimensional "color" space in the GISS computer algorithm. The values along each of the four axis in the color space represent the radiant energy received by the satellite in one of the four Landsat multispectral bands. Observations that lie in a similar direction from the origin in the four-dimensional color space are said to be similar in color regardless of their total radiant energy. The distance of an observation from the origin is a measure of the total radiance associated with that vector.

The GISS computer algorithm is primarily designed to combine observations similar in color into the same classification category. There is provision for evaluating brightness differences between pixels and for weighting these differences in with the color discriminant when constructing the classification categories.

Initial analysis of Landsat CCTs indicated that a set of snow cover/vegetation categories can be discriminated from the October 1977 through May 1978 CCTs. Ground truth data taken confirm that water equivalent differences occur for the mapped snow cover/vegetation categories.

The SSARR (Streamflow Synthesis and Reservoir Regulation) model is used each spring in the Saint John River Basin for flood forecasting. One of the inputs to this model is water equivalent of the snow in each subbasin at the beginning of the forecast period. Conventionally, this input is derived from the existing snow course network throughout the basin. As an alternative, the areal extent of these computer-mapped snow cover/

vegetation categories is being used to derive estimates of water equivalent of snow in each subbasin for a given spring snowmelt event. The SSARR model will be run with each set of snow cover inputs to determine if the techniques developed during this study will provide hydrologic information which improves flood forecasting in cold regions.

Computer analysis and interpretation of the Landsat CCTs for the 1978-79 winter season is continuing for the Upper Saint John River Basin. The third year's data of ground truth correlated to the satellite passes will also be obtained this winter season. In addition, the remote sensing study will be extended to the Sleepers River Research Watershed, Vermont and a watershed in the Northwest to further verify the computer techniques developed for the Upper Saint John River Basin.

AN OVERVIEW AND INTRODUCTION TO NCIC

Thomas Burger

National Cartographic Information Center (NCIC)
U. S. Geological Survey
Reston, Virginia 22092

INTRODUCTION TO NCIC

The National Cartographic Information Center, NCIC, was organized to collect and sort out descriptions of all the types of cartographic data available today from Federal, State and local government agencies and, where possible, from private companies in the mapping business. Within the government, NCIC is the information and map data distribution branch of the Geological Survey's National Mapping Program. We can help you find the answer to almost any type of cartographic question with emphasis on finding the right cartographic product for your needs.

SERVICES-RESEARCH

Through its five regional offices and numerous State affiliates, NCIC can research all types of cartographic information. For example, NCIC is sometimes asked to discover the original path of a now out-of-existence railroad. To do this, staff researchers might track down old Geological Survey maps that trace the rail line, or perhaps contact colleagues at the Library of Congress, the National Archives and Records Service, or associations of railroad historians to find the necessary maps or surveying notes.

NCIC's professional researchers also can be called upon to answer modern mapping inquiries that might deal with everything from providing the number of bits-per-inch on a computer file of elevations to finding an infrared satellite image of San Francisco Bay.

SERVICES-HANDOUTS, LEAFLETS AND SO ON

The type of information you receive from NCIC will depend on your request.

Some requests are answered by either a telephone call or a letter from the researcher who sought out the information you need.

Often, if you are asking about aerial photographs or a type of map or chart, NCIC will use one of its four computer information systems to quickly search through thousands and thousands of product descriptions. So, sometimes you will receive an easy-to-read computer printout with the information you need, whether its the address of an agency holding 1943 soil maps or a list of the aerial coverage available over Sioux City, Iowa.

Sometimes your question can be answered best by a leaflet or a simple handout. Quite often, NCIC researchers may have to contact you for more information so they can find the best answer for your inquiry. Most of NCIC's research services are free. If a charge is necessary, we will inform you before the research is started.

LIST OF PRODUCTS THAT NCIC HAS INFORMATION ABOUT

NCIC has, on tap, information about the following cartographic products:

U.S. Forest Service aerial photographs, National forest maps, and recreation maps; Burea of Land Management cadastral surveys, aerial photographs, Federal land maps, and land use maps, Bureau of Reclamation aerial photographs and river surveys; U.S. Geological Survey aerial photographs, topographic maps, orthophotomaps, county maps, regional maps, State maps, United States maps, polar-region maps, satellite image maps, lunar and planetary maps, geophysical maps and charts, geologic maps, Federal water resource development maps, bathymetric maps, hydrologic and flood-related maps, river surveys maps, mineral and energy resources maps, the National Atlas, geodetic control lists and diagrams, map and aerial photograph certifications, lists and gazeteers of geographc names, open file reports, flood prone area maps, land use maps, boundary information, color separation materials, WRD river basin maps, Department of Census demographic maps and SMSA maps; Central Intelligence Agency world maps, National Oceanic and Atmospheric Administration climate maps; Corps of Engineers river navigation charts, topographic maps, geodetic surveys; Federal Highway Administration transportation maps and county highway maps; Federal Power Commission utility maps; Bureau of Indian Affairs Indian reservation maps; Tennessee Valley Authority aerial photographs, topographic maps, bathymetric maps, recreation maps, nautical charts, utility maps, and geodetic surveys; Mississippi River Commission topographic maps and river charts; International Boundary Commission maps and international boundaries; Library of Congress maps, charts, atlases, and globes; Agricultural Stabilization and Conservation Service aerial photographs; Soil Conservation Service aerial photographs, Landsat image maps, and soil survey maps; National Archives and Records Service aerial photographs, maps, and charts; National Aeronautics and Space Administration aerial photographs, space photographs, and space exploration photographs; Defense Mapping Agency aerial photographs, topographic maps, hydrologic maps, nautical charts, aeronautical charts, lunar and planetary maps, military installations maps, digital terrain tapes; National Ocean Survey aerial photographs, planimetric maps, nautical charts, aeronautical charts bathymetric maps, historical maps, geodetic control, flood evacuation maps, topographic maps, and coastal zone maps, and that's only the Federal cartographic information.

SERVICES-ORDERING

In addition to our research services, NCIC can also take your order for National Mapping Program map data products. These items are the by-products of the Program's topographic mapping process. For example, reproductions of many of the aerial photographs used to make today's maps can be ordered through any NCIC office. Often farmers and cattle ranchers like to have low-altitude photographs of their farms and ranches. You don't have to live in the country to enjoy a photograph of your area either. One of the most popular photographs that can be ordered through NCIC is a color photograph of New York City that shows a panaroma of the Statue of Liberty, the New Jersey coast, Queens, and Manhattan Island from the Battery to midway up Central Park.

Landsat satellite images are another popular product available through any NCIC office. These are enhanced black-and-white or unusually colored portraits of selected geographic areas around the globe.

More unusual items are the map size film positives and negatives of the separate features and/or colors that are prepared for printing each Geological Survey topographic map. Map separations either singly or composited to order are usually purchased by other Federal and State agencies or private mapping companies so they can selectively create their own maps using only part of the information that appears on a standard National Mapping Program topographic map. For example, a State agency planning group in Missouri might need maps showing only open water and drainage patterns in an area without the highway system, county boundaries, and so on. This agency would order only film separations which show drainage.

Because of the trend in modern maping toward digital mapping, recording map information in computer files has become an integral part of the National Mapping Program. NCIC distributes nationwide a file of digital terrain tapes, records of the elevations on the Defense Mapping Agency's 1:250,000-scale series of maps. NCIC will handle the distribution of the National Mapping Program's digital data products as they become available.

<u>LIST OF PRODUCTS THAT CAN BE ORDERED THROUGH NCIC</u>

NCIC can accept orders for the following cartographic products:

Advance prints, color separates, feature separates, out-of-print map reproductions, land-use and land-cover and associated maps, slope maps, digital terrain tapes, maps on microfilm, orthophotoquads, aircraft block photos, aircraft irregular photos, manned spacecraft images, Landsat images, computer-enhanced Landsat scenes, computer compatible tapes of Landsat data, 35-mm viewing slides, transformed prints, Kelsh plates, photoindexes, APSRS State-base graphics, microfiche indexes of aerial and space images, geographic computer searches, geodetic control data, reproductions of microfiche of State place names, county maps, ER-55 plates, topographic maps on rolls of 35-mm microfilm, geographic coordinates of various U.S. and selected world names, microfiche of NCIC's map catalog, autopositives, and some NCIC regional offices sell U.S. Geological Survey ;topographic and thematic maps.

To enter data

NCIC is interested in broadening their data base to include information on all useful cartographic data. Anyone interested in making their data available to the public is encouraged to contact the Chief, Data Acquisitions at the National Headquarters address below. Encoding of aerial photo, map, and other cartographic data will be arranged to fit your needs and capabilities.

For more information

To use NCIC research services or to order National Mapping Program products fill in and mail the attached card or telephone or write to one of the following NCIC offices.

National Headquarters

National Cartographic Information
Center
U.S. Geological Survey
507 National Center
Reston, VA 22092
703 860-6045
FTS 928-6045

Regional Offices

NCIC-East
U.S. Geological Survey
536 National Center
Reston, VA 22092
703-860-6336
FTS 928-6336

NCIC-Mid-Continent
1400 Independence Road
Rolla, MO 65401
314-364-3680, ext. 107
FTS 276-9107

NCIC-NSTL
U.S. Geological Survey
National Space Technology Laboratories
Building 1100
NSTL Station, MS 39529
601-688-3544
FTS 494-3544

NCIC-Rocky Mountain
U.S. Geological Survey
Box 25046, Stop 504 Federal Center
Denver, CO 80225
303-234-2326
FTS 234-2326

NCIC-Western
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025
415-323-8111, ext. 2427
FTS 267-2427

Federal affiliates NCICs

Tennessee Valley Authority
200 Haney Building
311 Broad Street
Chattanooga, TN 37401
615-755-2148
FTS 854-2148

State Affiliate NCICs

NCIC has established affiliated offices with many State governments. For the address of the nearest one, ask your nearest regional NCIC office.

SPOT - FRENCH SATELLITE PROGRAM

FOR REMOTE SENSING

Gilbert WEILL

Centre National d'Etudes Spatiales
Paris, FRANCE

France is presently developing within Europe (in association with Belgium and Sweden) a satellite system for Earth Observation applications. The system, called SPOT, is based on the concept of a standard satellite platform and its associated ground control and command station. The platform is designed to accomodate various types of payloads, all earth-oriented, weighing up to 800 Kg, provide them with appropriate structural support, attitude and orbit control, power supply, operation monitoring and management capability. It interfaces with the launcher and ground control and command stations. The ground station provides for satellite tracking, orbit and attitude determination, house-keeping monitoring, it issues the commands for preprogramming all satellite activities, including those of the payload instruments : it can also command satellite functions in a realtime mode. The satellite power generator is designed to provide up to 1800 W B.O.L. according to mission. The whole space system is optimized for sun-synchronous orbits of 600 to 1200 Km altitude, and a wide choice of local times at the orbital node. The pointing accuracy is in the range of 0.1 deg.

The first mission is planned for launching in early 1984. Land Use, Vegetation assessment, Geology, Cartographic application tests rank high among the themes which the mission will investigate. The mission specific payload is comprised of 2 identical optical instruments, 2 on-board recorders and an image telemetry system at 8 GHz (X band).

Each instrument is equipped with multilinear array detectors; a pointable (cross-track) front mirror allows for the 60 Km field to be placed anywhere within a 950 Km wide band, and therefore permits frequent access to specific sample areas. It can operate in a color mode - 3 spectral bands - with a ground sampling step of 20 m and/or a Black and White mode - with a ground sampling step of 10 m. Each mode produces 25 Mbits/second data stream. Two streams are routed to the downlink TM or to the recorders.

The orbital choice for the first mission is a circular, sun-synchronous orbit, altitude 832 Km, providing an orbital cycle of 26 days (369 tracks). The local time at the descending node is 10.30 a.m. This orbit permits stereo pairs to be acquired, with a reasonable B/H ratio at most latitudes, within 24 hours.

Worldwide access to the satellite data is planned through the french image receiving facility, and is a definite possibility through foreign direct-receive X band stations.

A user product manufacturing facility will be installed in Toulouse ; products will be available in both numerical CCT and photographic forms, at three levels of geometric accuracy, ranging from nearly raw to cartographic quality.

While the first mission program is about to enter the industrial realization phase (first satellite and spare), further missions are in the conceptual phase. In particular, the European Space Agency (ESA) has conducted "Phase A" studies of two payloads for land and oceans including a Synthetic Aperture Radar.

References :

1°) Centre National d'Etudes Spatiales - SPOT - Phase 1 Report, TOULOUSE, March 1977

2°) CABRIERES B., J.C. CAZAUX, G.WEILL - SPOT - First French Remote Sensing Satellite - Geometrical Performance. Proceedings of 13th International Symposium on Remote Sensing of Environment, Ann Arbor, MICHIGAN, 1979.

3°) BAUDOIN A., D. KIRSNER, J.C. CAZAUX : Terrain modeling and Geometric correction using the SPOT Satellite. Proceedings of 13th International Symposium on Remote Sensing of Environment, Ann Arbor, MICHIGAN, 1979.

4°) THOMPSON L.L. - Remote Sensing using Solid State Array Technology Photogrammetric Engineering and Remote Sensing, 45 Number 1, 1979.

5°) CHEVREL M., M. COURTOIS, G. WEILL - SPOT First French Remote Sensing Mission ; submitted to Photogrammatric Engineering and Remote Sensing.

EARTH RESOURCES - CURRENT SYSTEMS AND FUTURE PLAN

Pitt G. Thome

Director Resources Observations
NASA Headquarters

ABSTRACT

The current status of NASA's earth resources systems and plans for future systems are briefly reviewed.

Both Landsat-2 and -3 are performing at near nominal levels despite some minor systems problems. The Multispectral Scanner (MSS) on both spacecraft are experiencing occasional line start errors, but the anomaly can be rectified during ground data processing; one wide band tape recorder on each spacecraft continues to operate nominally. The gas for attitude control of Landsat-2, after four and one-half years of operation, is slowly nearing depletion; the spacecraft has been placed in a gas-saving mode to ensure spacecraft operation until Landsat-D is launched.

Landsat-D is progressing on schedule for a late-1981 launch. The instrument complement will include both the four-band MSS for data continuity and the seven-channel Thematic Mapper with broader spectral capability, improved spectral resolution, and a 30m spatial resolution.

In order to provide improved temporal resolution without additional satellites, a pointable sensor utilizing multilinear array technology is under consideration. The specific spectral range, spatial resolution, and sensor capability are still under study. Multilinear array imaging, systems technology, and capability are reviewed.

The Heat Capacity Mapping Mission, launched in April 1978, has acquired much useful data; the radiometer continues to operate nominally. Some limited results of the data analysis are presented.

Stereosat, a potential 1981 new initiative, would provide global stereoscopic imagery that would prove invaluable for mineral and petroleum surveys and for global geomorphological studies of surface landforms. The utility of the data are reviewed.

The Large Format Camera is planned for flight on the Shuttle in 1981. Specific system parameters and capability are discussed.

Synthetic Aperture Radars (SAR) for earth resources studies will be flown initially in late 1980 on the Space Shuttle. An L-band SAR, utilizing spare components from the Seasat SAR, is expected to provide

valuable data for geological investigations. Subsequently, a dual frequency (possibly X- and C-bands), multipolarized system will be flown to provide supplementary data and to determine the optimum system parameters for an earth resources SAR.

All Vugraphs used by Mr. Thome during his presentation are not included in the Proceedings. The following Vugraphs have been selected because they provide additional information that is not contained in the abstract.

LANDSAT OPERATIONS

REMOTE SENSING TECHNIQUES

MULTISPECTRAL LINEAR ARRAYS

ADVANTAGES AND DISADVANTAGES OF LINEAR ARRAY SENSOR SYSTEMS

HEAT CAPACITY MAPPING RADIOMETER

WHY STEREOSTAT?

LARGE FORMAT CAMERA FOOTPRINT OVER MASSACHUSETTS

LARGE FORMAT CAMERA

CURRENT OPERATING POSTURE

LANDSAT-2

- U.S. REAL TIME COVERAGE—ALL WEATHER
- PRIME FOR FOREIGN STATION REAL TIME COVERAGE
- FOREIGN COVERAGE REQUIRING TAPE RECORDER
- SPACECRAFT IN ACS GAS SAVING MODE

LANDSAT-3

- U.S. COVERAGE—30% OR LESS CLOUD COVER WITH MSS
- SEASONAL COVERAGE WITH RBV (ONE CLOUD-FREE SCENE EACH SEASON OVER ALL U.S.)
- FOREIGN COVERAGE REQUIRING TAPE RECORDER
- REQUEST FROM FOREIGN RECEIVING STATIONS FOR RBV DATA

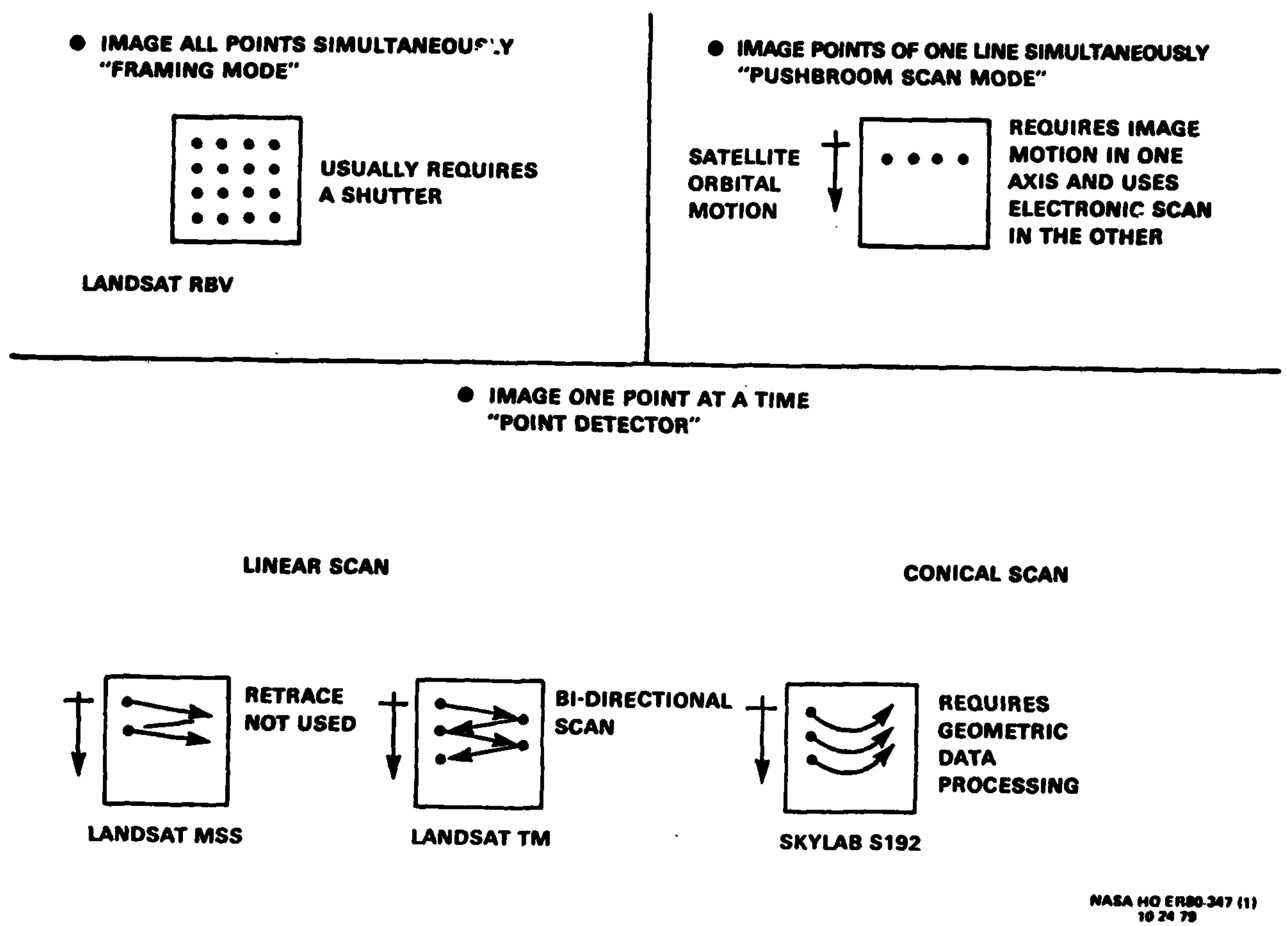
PRIORITIES FOR TAPE RECORDER USAGE

- DISASTERS OR EMERGENCY EVENTS
- AGRICULTURAL
- SHALLOW SEAS MAPPING
- SPECIFIC U.S. STUDIES
- SPECIFIC FOREIGN STUDIES
- OTHER REQUESTS

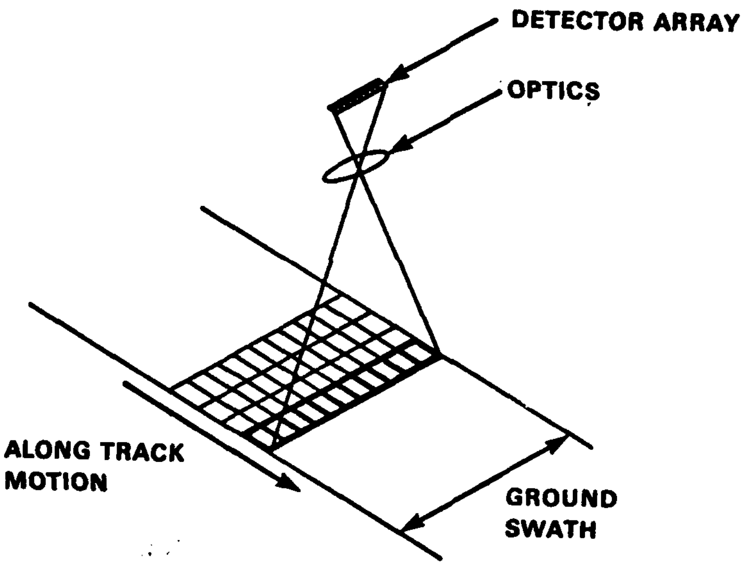
PROCEDURES ESTABLISHED FOR TASKING SATELLITE FOR SPECIAL COVERAGE

NASA HQ ER79-3310(1)
REV. 10-30-79

LANDSAT OPERATIONS



REMOTE SENSING TECHNIQUES



NASA HQ ER80-346 (1)
10-24-79

MULTISPECTRAL LINEAR ARRAYS
(PUSH BROOM SCAN MODE)

ADVANTAGES

- IMPROVED RADIOMETRIC SENSITIVITY
  - LONG INTEGRATION TIME
- COMPLEX MECHANICAL SCAN MECHANISMS NOT REQUIRED
- DETECTOR POSITIONS CAN BE PRECISELY MAPPED
  - CARTOGRAPHIC CONSIDERATION
- PROVIDES SMALLER, LIGHTER WEIGHT SYSTEMS

DISADVANTAGES

- LARGE NUMBER OF DETECTORS REQUIRED
- MORE COMPLEX CALIBRATION

NASA HQ ER80-344 (1)
10-24-79

ADVANTAGES AND DISADVANTAGES OF LINEAR ARRAY SENSOR SYSTEMS

- TWO CHANNEL SCANNING RADIOMETER

	CHANNEL 1	CHANNEL 2
DETECTOR	UNCOOLED SI PHOTO-DIODE	Hg - Cd - Te
RANGE	0.5 - 1.1 μ (REFLECTED)	10.5 - 12.5μ (EMITTED RADIATION)
ACCURACY	.2 mw/cm^2 (NER)	0.3° K AT 280° K (NEDT)
SPATIAL RESOLUTION	500 x 500 m	600 x 600 m

SCAN RATE 14 REVOLUTIONS/SEC

- SWATH WIDTH 716 km

- INFORMATION BANDWIDTH 53 KHz/CHANNEL

NASA HQ ER80-340 (1)
10-24-79

HEAT CAPACITY MAPPING RADIOMETER

APPLICATIONS OF STEREOSCOPIC IMAGER

- FUNDAMENTAL REQUIREMENT FOR MINERAL AND PETROLEUM EXPLORATION SURVEYS
- PROVIDES CRITICAL INFORMATION ON LANDFORMS, FAULTS, FRACTURES, AND DRAINAGE PATTERNS REQUIRED FOR MAJOR ENGINEERING PROJECTS
- GREATLY IMPROVES THE USEFULNESS OF MONOSCOPIC IMAGERY

SCIENCE UTILIZATION

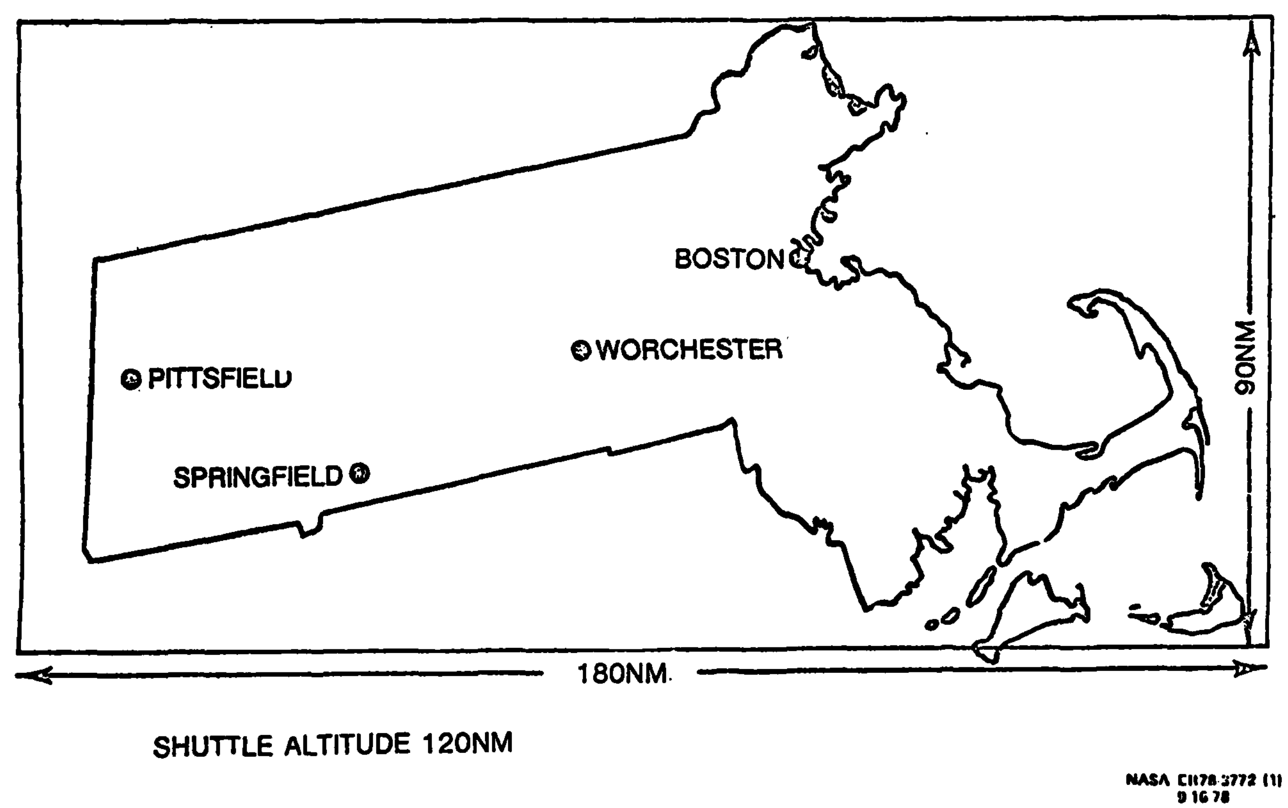
- PERMITS QUANTITATIVE GLOBAL GEOMORPHOLOGICAL STUDIES OF SURFACE LANDFORMS
- CAN BE USED WITH ANCILLARY DATA (E.G. MAGNETIC AND GRAVITY SURVEYS)

NEED

- NO UNIFORM SET OF GLOBAL STEREOSCOPIC IMAGERY AVAILABLE
- STEREOSCOPIC IMAGERY LACKING FOR MANY REGIONS OF THE WORLD
- NO OTHER PROGRAM CURRENTLY PLANNED TO OBTAIN AN ORGANIZED SET OF GLOBAL STEREOSCOPIC DATA
- BROAD SEGMENT OF THE GLOBAL GEOSCIENCE USER COMMUNITY WILL UTILIZE GLOBAL STEREOSCOPIC DATA

NASA HQ ER79-[illegible](1)
8-1-79

WHY STEREOSAT?



LARGE FORMAT CAMERA FOOTPRINT OVER MASSACHUSETTS

FOCAL LENGTH	30.5 CM
FORMAT	23 x 46 CM
APERTURE	F/6.0
RESOLUTION	80 LINES/MM AT 2:1 CONTRAST
EXPOSURE TIMES	3 - 24 M/SEC
CYCLE TIME	7 - 45 SEC
FILM CAPACITY	2400 FRAMES (1200 M)
DIMENSIONS	1.3 M x 0.6 M x 0.9 M
WEIGHT	340 KG
POWER	0.3 KW AVG.

NASA HQ ER80-337 (1)
10-24-79

LARGE FORMAT CAMERA

RESEARCH FOR INFORMATION EXTRACTION FROM AERIAL IMAGERY

Dr. Robert D. Leighty

Research Institute
U. S. Army Engineer Topographic Laboratories
Fort Belvoir, VA 22060

ABSTRACT

The U. S. Army Engineer Topographic Laboratories is investigating a number of approaches to information extraction from aerial imagery. Two approaches will be discussed in this paper: Automated feature extraction research and computer-assisted photo interpretation research. The discussion of automated information extraction indicates present day capabilities of automated systems, problems facing automated information extraction, and directions which basic research must take to achieve automated "smart analysis systems" in the distant future. The discussion of computer-assisted photo interpretation will describe the research system now being developed and experiments for research which is expected to have value in the near future for increasing the quality and efficiency of the total information extraction processes.

INTRODUCTION

The research and development program of the U. S. Army Engineer Topographic Laboratories (USAETL) contains a large number of efforts involving image information extraction. This attests to the wide variety of problems, the diverse nature of potential solutions, and perhaps most important, to the real and urgent need for improved information sources and the ever increasing requirements for better and more timely information. Presently, and with few exceptions, the photo interpreter represents the only proven means for information extraction from aerial imagery in a production environment. The interpretation tasks are labor intensive, time consuming, and often require a high level of expertise. For many organizations in the government, the improvement of acquisition systems and the need for rapid data extraction has led to research and development seeking new and improved methods and systems for extracting information from aerial imagery.

USAETL is conducting research at several levels in the extraction of natural and cultural data from aerial imagery. These levels range from assisting the operational photo interpreter with his present day problem solving and data manipulation tasks to basic research for automated pattern recognition systems of the future. Between these extremes USAETL is developing a large interactive digital image processing research facility

(DIAL) having the capabilities of performing a wide range of functions of potential value to an image interpreter. Grey scale manipulation, geometric warping, scrolling, overlaying graphics, stereo mensuration, and anaglyphic stereo presentation are representative functions. Other examples of research activities at USAETL address image information extraction and presentation related to manual methods and techniques for the expert photo interpreter interested in soil, rock, vegetative and cultural patterns; Landsat data analysis techniques for small scale terrain material distribution studies; and special purpose thematic mapping for Military Geographic Information applications.

This short paper can not begin to do justice to the USAETL research in for information extraction from aerial imagery. Therefore, two selected research approaches will be discussed which represent one view of the wide range of the USAETL research. The first approach will deal with automated extraction of information from aerial photography in the distant future. This overview will be presented to acquaint the reader with the capabilities of present day automated systems, the problems facing automated information extraction, and the directions which basic research must take to attain "smart analysis systems." The second approach to be reviewed deals with computer-assisted photo interpretation research system employing today's technology to assist the human in his decision-making and data manipulation processes. This research is expected to have significant value in the near future for increasing quality and efficiency of the total information extraction processes.

RESEARCH FOR AUTOMATED INFORMATION EXTRACTION

An ultimate goal for an automatic aerial image information extraction system could be a desk-sized system containing a drawer into which a roll of aerial imagery is dropped, a few buttons pushed, and in a few seconds the desired information appears. Enormous amounts of money have been spent to develop automated systems with far less ambitious goals. From this we have learned that total automation is an unrealistic goal. More realistically, partial automation can be applied to the more mundane and repetitive problems where solutions are relatively well defined. Though this may seem to be a retraction from the desired purpose and scope of automation, it does historically place automation in an achievable context.

The lack of great automation successes should not imply that we are wasting research money in this direction, but rather that the direction must be more sharply focused. In this section capabilities of present day semi-automated systems will be outlined and the major problems facing automation will be indicated. The section will close with a brief discussion of research directions leading towards "smart" systems for the future.

Present Day Systems

The key to successful automation is to ferret out the simple, but important, tasks amenable to automated solutions. In some cases this can only be achieved by decomposing difficult tasks into simpler sub-tasks that lend themselves to clearer definition and have sufficient constraints in terms of available or achievable capabilities. Additionally, constraints may be added to yield a less general solution but render the problem tractable. A vivid example of adding constraints to a pattern recognition problem is seen in optical character recognition systems of today where well formed (i.e., size, shape, position, etc.) alphanumeric symbols can be recognized but free hand writing or back-of-the-letter printing is not within the capabilities of automatic reading systems.

An example of automating a simple but important task with aerial imagery involves the cloud screening system being developed by USAETL for the Defense Mapping Agency. In terms of pattern recognition from aerial imagery there perhaps could not be a simpler problem than detecting clouds or no clouds. In the mapping and intelligence communities cloud screening is an important problem because clouds obscur the landscape and their recognition and delineation from the aerial images is usually a simple but labor intensive manual task. Research at USAETL indicated that clouds could be detected with about 98% accuracy (Ref. 1), and a large format optical screening system is being assembled under contract to potentially allow screening rates of about 25 frames per minute in a production environment with about 1600 samples per frame. This same research capability has indicated potentials for automatic analysis for image information content screening and ocean wave analysis, (Ref. 2).

Certainly there are other limited successes in automated information extraction from aerial imagery; notably with the use of Landsat images. In all cases, however, these must be considered special purpose, semi-automated capabilities.

Difficulties Facing Automated Pattern Recognition

It is instructive to briefly mention the major difficulties facing automated pattern recognition from aerial imagery. The prime reason for the limited success to date concerns the variability of natural and cultural terrain features. If every feature class had a unique signature or fingerprint the task might be tractable, but this is not the case, at least in a simple sense. A second prime reason for difficulty concerns the environment and its relation to the terrain features and the images. For example, seasonal changes in vegetation and crops, seasonal and diurnal changes in solar illumination, and the effects of rain, snow, fog, haze, and smoke, all tend to change aerial images in a temporal sense. The aerial sensors provide added variability for in most cases the images are acquired for the purposes of qualitative analysis by interpreters rather than for quantitative analysis by machines. Today's sensors swamp us with data due to higher resolution and more rapid acquisition capabilities, but rarely do we have the luxury of working with images from sensors which best suit the problem. For example, black and white panchromatic photography is most commonly available, and we know that this image type compresses the visual electromagnetic spectrum (from which we commonly see colors) into a limited number of grey tones. Images obtained at different scales and formats add additional variability to the analysis problem.

Another prime reason for our limited success in automating information extraction from aerial imagery involves our present state of analysis capabilities. Consider the statistical approaches wherein bean counting algorithms classify a pixel by brute force as wheat or water or whatever by the numbers which represent grey tone or multispectally sensed data. Most algorithms consider the numbers from each pixel only with respect to a statistical population as though they were drawn from a hat; each pixel is classified in turn from start to finish in a global fashion without any apriori information of physical value and without considering the environment, etc. This characterization of statistical pattern recognition is perhaps unfair, however we can say, without bias, that the present state of our analysis software is very unsophisticated.

Toward Smart Systems

Today's research is expected to provide potential solutions for problems of the future. This generalization pertains also to the above listed difficulties facing automated information extraction from aerial imagery. The author believes this research should be directed toward the development of "smart" systems. Here "smart" is loosely defined as some measure of decision quality usually attributed to humans but not to machines. In essence, this is the definition of artificial intelligence and several organizations, mostly at the university level, are conducting basic research in pursuit of artificial intelligence methods and techniques leading to smart systems of the future (Ref. 3). The Defense Advanced Research Projects Agency (DARPA) is sponsoring "Image Understanding" basic research in a number of these organizations. Under a separate memo of understanding with the Defense Mapping Agency, DARPA will have a prototype interactive workstation available for testing with 1983 that will incorporate artificial intelligence concepts for automatically extracting image information related to selected tasks which are yet to be defined.

The central concept of the image understanding relates to knowledge-based analysis wherein rule-based inference techniques enable expert judgemental knowledge about a specific problem domain to be represented as a collection of discrete rules (Ref. 4). Each rule states that if certain premises are known, then certain conclusions can be inferred. Interactive rule-based analysis has been used for diagnosing bacterial infections (Ref. 5) and pertinent computer-aided consultant research is being conducted by Stanford University and Stanford Research Institute (Ref. 6). It is believed that the development of knowledge-based image analysis will determine the generality and applicability of automated pattern recognition to complex tasks in the future.

Now that the concept of a smart system has been loosely defined, the difficulties facing automated pattern recognition, mentioned above, can be reviewed in the smart system context. For example, the variability of natural and cultural terrain features and the temporal environmental variations were indicated to present the major difficulties impeding present day automated image analysis techniques. Given the tools associated with a smart system the general rules of nature for a given geographic area can be encoded as rules for a knowledge-based system. Thus, our pattern recognition system can begin to use knowledge from geology, physiography, ecology, meterology, etc. as a base and specific information of the time and place of imaging to coordinate the image with the knowledge base. Likewise, the knowledge base can include rules for different sensors in a manner which would normalize selected types of sensor variations. The difficulties associated with image scale and format can be handled in a similar manner. And perhaps the greatest benefit of smart image analysis systems will be most evident in upgrading the state of our image analysis capabilities from brute force statistical approaches to analysis techniques based on logic. Statistical algorithms will be applicable in smart systems, but as low level classification techniques selected and controlled by logic structures.

Smart systems will allow us to integrate our knowledge of the real world area under study. Digital cartographic data bases are expected to play key roles because for large areas of the earth's surface we will have knowledge of where major patterns of vegetation, water, roads, bridges, etc. are located. In addition, terrain elevation data will be available for analysis of landscape configurations. Suppose we were interested in locating all structures associated with flood plains of a given river system. With knowledge data base which includes rules that associate "flood plains" with certain terrain configurations and the occurrence of "rivers" and "streams", and structures with access roads, etc., and if the imagery is coordinated with the digital cartographic data base, it would seem that the recognition and analysis tasks would be much more efficient than those afforded by present day techniques.

It must be emphasized that we have been discussing smart systems which we hope will evolve in the distant future from present and future basic research efforts. Now let us turn to research for extracting information from aerial imagery which could help us in the very near future.

COMPUTER-ASSISTED PHOTO INTERPRETATION RESEARCH

Since manual photo interpretation presently provides the only reliable operational capability for extracting a wide range of information from aerial imagery, it is essential to provide the interpreter with the facilities that will make him more efficient in his total work effort. Considerable attention has been given to the development of quality stereoscopic optical viewing systems for the photo interpreter but little attention has been devoted to the development of procedures and equipment to help the interpreter extract, record, and manage information directly from the stereoscopic imagery. This total work effort not only deals with the process of annotating stereophoto overlays with symbols and lines indicating classifications and areal extents of terrain features pertinent to the problem at hand, but additionally to processes such as selection imagery for the study, retrieving available collateral information from the files related to the problem at hand and the area under study, and formating the output data into a product ready for distribution. USAETL is presently addressing this problem area and will have a research test-bed system in operation by March 1980 (Ref. 7).

Our basic objective is investigate new and innovative computer-assisted approaches to a wide range of present day operational photo interpretation and data processing applications. An initial computer-assisted photo interpretation research (CAPIR) system has been defined and is being procurred and assembled from state-of-the-technology components. It will basically provide a digital data encoding and management system for the photo interpreter to accomplish the total work effort. The photo interpreter will provide the difficult-to-automate capabilities for the decision-making and control function selection. Representative experiments have been outlined to demonstrate applications and cost effective benefits which will indicate an evolution of enhanced system capabilities and point to directions of future research. The system will now be described and this will be followed by a short discussion of the planned application tests.

CAPIR System

Design of the CAPIR system was based on the prerequisite that all components were off-the-shelf, so to speak. Two recent developments have profoundly influenced the nature of the system: The first has been the evolution of the analytical point positioning system (APPS) family of stereoscopic instrumentation which has led to a low-cost, commercial analytical plotter, and the second was the Wetlands Analytical Mapping System (WAMS) which has demonstrated the potential for on-line stereoscopic digitization of aerial photography to create and manage digital geographic data bases (Ref. 7).

The APPS-I prototype instrument was fabricated at USAETL and tested in 1972 as a simple, field-deployable point positioning system that integrated a Zeiss Stereotope, Bendix Datagrid, and a Hewlett-Packard 9810A calculator to operate on a data base of annotated stereo aerial photographs with predetermined camera parameters and control point coordinates (Ref. 8). In operation, two photos of a stereo pair are mounted on the instrument stages, control points are measured for system initialization and verification, then X, Y, Z coordinates for any number of points in the stereomodel are computed after centering on the point of interest and manually clearing x and y parallax. APPS-III is a non-ruggedized commercial version of the APPS that was developed under internal funding by IDEAS, Inc. and used by Autometric, Inc. as a stereo digitizer in the WAMS for the U. S. Fish and Wildlife Service. It uses a Bausch and Lomb Zoom 240 Stereoscope and is interfaced to a Hewlett-Packard minicomputer. The APPS-IV is a commercial, medium-accuracy (RMS errors of less than 10 micrometers) analytical plotter announced by Autometric, Inc. in late 1978 (Ref. 9). It utilizes a minicomputer, the Bausch and Lomb Stereo Zoom Transfer, and several microprocessors in a compact desk-sized workstation. An option provides servocontrolled photo stages which maintains the stereomodel as stages are slewed in x and y directions in the field of a stationary cursor. Thus, the APPS-IV permits convenient stereo digitization in ground coordinates of point, line, or areal features.

WAMS was developed by Autometric, Inc. for the National Wetlands Inventory Project, U. S. Fish and Wildlife Service, to provide a computer-based system to delineate, classify, and inventory the wetlands of the United States (Ref. 10). It utilized an APPS-III to create a digital data base and has a software system with three distict on-line capabilities: aerotriangulation of source imagery; digitization for data base creation; and editing and data base management functions.

The CAPIR is built on the foundation of the WAMS software and the APPS-IV computer-interfaced stereoscope, then systematically augmented in hardware, software, and firmware to provide additional capabilities. As shown in Figure 1 and Table I, the CAPIR system is composed of five subsystems. The stereoscopic workstation provides the interpreter with a friendly man/machine interface and consists of the basic APPS-IV analytical plotter with servoed photo stages; internal firmware to allow on-line extraction of terrain elevation data by profiling; graphic superposition, wherein computer-generated graphics are optically superimposed in the stereomodel; and a CRT terminal. The monoscopic workstation subsystem supports digitization from map sheets and orthographic source materials for aerotriangulation and data base entry. The digital image workstation is designed to support future research in semi-automatic pattern recognition with the goal of developing techniques to permit the gradual transfer of selected decision-making responsibilities from the interpreter to the computer. This subsystem consists of an image sampler, an image display, and a CRT terminal. The system minicomputer and software subsystems complete the initial configuration.

CAPIR Application Experiments

Six experimental areas have been initially identified by elements of USAETL for research efforts. These are listed in Table II with the proposed research tasks and will be briefly discussed.

The objective of the point positioning and mensuration experiments is to develop improved photo interpretation methods for point positioning and stereo mensuration from metric and non-metric aerial imagery of different scales and formats for a selected set of measurement applications.

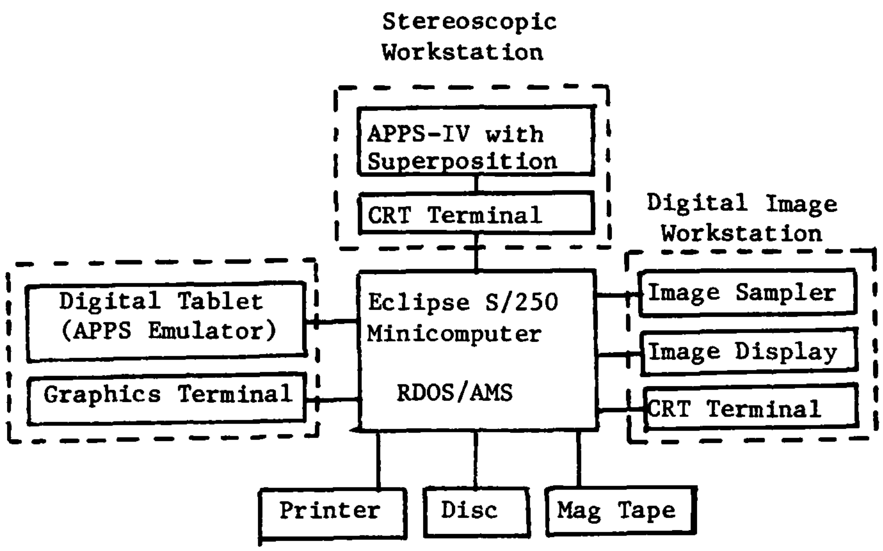


Figure 1. Computer-Assisted Photo Interpretation Research (CAPIR) Facility

The objective of the geographic information systems experiments is to demonstrate procedures for the creation of digital geographic data bases and develop computer graphics superposition with the stereomodel to permit validation, editing, updating, and intensification of derived data bases. Interactive spatial analysis of derived geographic data will provide optional display of synthesized products within the stereomodel.

The multi-source data fusion experiments have the general objective of investigating analysis and integration of data from dissimilar imagery and collateral sources through exploitation of common ground coordinate systems for superposition of data base information in the stereomodel.

Studies for elevation data extraction with the CAPIR system will evaluate concepts for generation, inspection, and editing of digital elevation data to support photogrammetric data production and terrain analysis.

Knowledge-based programming experiments will investigate the use of the computer to aid the photo interpreter's decision-making processes and will collect data to support knowledge-based terrain analysis basic research.

The objective of the semi-automated pattern recognition experiments is to conduct research in which the photo interpreter initializes a pattern recognition problem, invokes and evaluates the performance of selected automated classification procedures. Computer compatible tapes from the Recording Optical Spectrum Analysis system, when integrated with CAPIR image data, will simulate use of automated prescreening data to aid the interpreter.

TABLE I. CAPIR System Components

A. STEREOSCOPIC WORKSTATION

1. APPS-IV Analytical Plotter
2. Profiling firmware
3. Graphic superposition
4. CRT terminal

B. MONOSCOPIC WORKSTATION

1. Digital tablet (36" x 48" backlighted)
2. APPS-IV emulator for tablet
3. Graphics terminal

C. DIGITAL IMAGE WORKSTATION

1. Solid-state image sampling camera
2. Video processor with color monitor
3. CRT terminal

D. SYSTEM MINICOMPUTER AND PERIPHERALS

1. Data General Eclipse minicomputer with array processor
2. 20 Mbyte disc drive (interchangeable 10 Mbyte cartridge)
3. Magnetic tape drive (9 track, 800 bpi)
4. Character printer (180 characters/second)

E. SYSTEM SOFTWARE

1. Operating system: Data General RDOS
2. Principle programming language: FORTRAN V
3. WAMS software
4. Scientific subroutine library

TABLE II. Initial CAPIR Experiments

1. POINT POSITIONING AND MENSURATION

   a. Absolute positioning accuracy
   b. Direct mensuration of terrain features
   c. Quantification of vegetation parameters
   d. Computer-driven search and measurement of vertical obstractions
   e. Definition of parameters to establish an urban rubble model.

2. GEOGRAPHIC INFORMATION SYSTEMS

   a. Digital geographic data base operations
   b. Generation synthesized terrain data products

TABLE II. Initial CAPIR Experiments cont'd

c. Estimation of forest parameters from small-scale imagery.

3. MULTI-SOURCE DATA FUSION

   a. Use of multidate, multiscale imagery study of vegetation
   b. Intelligence fusion of collateral data in the stereomodel.

4. ELEVATION DATA EXTRACTION

   a. Production of digital terrain matrices
   b. Intervisibility models
   c. Terrain profiling in support of terrain analysis.

5. KNOWLEDGE-BASED PROGRAMMING

   a. Support for knowledge-based terrain analysis research
   b. Vertical obstruction pattern recognition
   c. Voice recognition and voice synthesis.

6. SEMI-AUTOMATED PATTERN RECOGNITION

   a. On-line sampling sensor and selected classification algorithms
   b. Joint CAPIR/ROSA experiments.

PROGNOSIS

Information extraction from aerial imagery is a many-faceted problem area lacking a unique solution. In this environment, the photo interpreter continues to provide the only viable general purpose capability and yet for many reasons this is not an acceptable solution for either current or future demands. Presently, automation can serve in assisting roles where individual subproblems have been partitioned into well-defined tasks. To think of general purpose automation for information extraction from aerial imagery is fool hearty at this time because the proper foundation has not been prepared. Instead, the rationale for interactive systems that retain the human control and decision-making functions will present valid research objectives in the coming years. We can apply existing technologies initially to assist the photo interpreter in his total set of information extraction processes by preparing the data for decision-making and managing the information after the decision process. Where subproblems are better defined the machine can suggest solutions which require tuning by the interpreter. Addition of these capabilities in a plausible and pragmatic manner will lead to the evolution of useful systems as well as approaches toward the development of smart operational systems.

Current with the bottom-ups approach to development of computer-assisted capabilities, we must develop top-down means for organizing and managing knowledge applicable to our problem areas. As rule-based decision-making matures, individual elements of the control and classification decisions can be accomplished by machine. Automation of these functions is dependent upon definition of interpreter logic in manner which the machine can trace or search for tractable solutions.

We should expect that highly automated systems for information extraction from aerial imagery will be a part of our production capabilities in the future if the proper research is provided as a foundation. Now, however, we must be content with assisting the interpreter in his domain while evolving to ever-improved capabilities. USAETL will continue to conduct research in these and other areas leading to smart interpreters, smart systems, and better means for extracting information from aerial imagery.

REFERENCES

1. Lukes, G. E. "Cloud Screening from Aerial Photography Applying Coherent Optical Pattern Recognition Techniques," Proc. SPIE, Coherent Optics in Mapping, Vol. 45, 265 (1974).

2. Lukes, G. E., "Rapid Screening of Aerial Photography by OPS Analysis," Proc. SPIE, Data Extraction from Film, Vol. 117, 132 (1977).

3. Winston, P. H. Artificial Intelligence, Addision-Wesley, 1977.

4. Duda, R. O., R. E. Hart, N. J. Nilsson, and G. L. Sutherland, "Semantic Network Representations, in Rule-Based Inference Systems," Technical Note 136, Artificial Intelligence Center, Stanford Research Institute, May 1977.

5. Shortliffe, E. H., Computer-Based Medical Consultants: MYCIN, Elsevier, N. Y., 1976.

6. Duda, R. O., P. E. Hart, and N. J. Nilsson, "Subjective Bayesian Methods for Rule-Based Inference Systems," Technical Note 124, Artificial Intelligence Center, Stanford Research Institute, January 1976.

7. Lukes, G. E., "Computer-Assisted Photo Interpretation Research System (CAPIR)," unpublished report, USAETL, September 1979.

8. Armstead, J. G., "Analytical Photogrammetric Position System (APPS) to Support the Field Army," Report ETL-TR-74-4, USAETL, 1974.

9. Greve, C. W., R. F. Bunn, and H. A. Niedzwiadek, "Current and Potential Applications of the APPS-IV Analytical Plotter," Proc. Amer. Soc. Photogrammetry, 1979, pp. 80-91.

10. Niedzwiadek, H. A., C. W. Greve, H. R. Pywell, "The Wetlands Analytical Mapping System," Proc. Amer. Soc. Photogrammetry, 1978, pp. 320-328.

EVALUATION OF MULTIDATE LANDSAT DATA FOR WATER QUALITY MODELING APPLICATIONS

John Adams
U. S. Army Corps of Engineers
Buffalo, NY 14207

Robert H. Rogers and Merv Walsh
Environmental Research Institute of Michigan
P.O. Box 8618
Ann Arbor, MI 48167

ABSTRACT

The objective of this research effort is to evaluate the ability of Landsat digital data to provide accurate land cover/use information. Specific applicability to models which evaluate agricultural nonpoint sources of water pollution is considered. Two technical issues are of concern: (1) with what precision can the Landsat data be correlated with a given geographic coordinate grid (in this case Universal Transverse mercator); (2) (and most importantly) how accurately can the land cover categories of interest be interpreted using Landsat data. This latter is determined by comparison of the Landsat interpreted categories with an existing digital format photointerpreted data base of known accuracy. This represents the first time that a large area of processed Landsat data has been quantitatively evaluated for classification accuracy.

The Landsat satellites are a potentially valuable tool for the Corps of Engineers in many of its programs dealing with water and watershed management. By providing repetitive computer compatible imagery of all parts of the United States (and the world), the data from these satellites offers the opportunity to inventory and regularly update the surface features or land cover of large geographic areas at very reasonable cost. The data has its limitations, however, most notably resolution (about 1.1 acre per data point) and the accuracy with which features of interest can be discriminated using the multi-band spectral characteristics. Before any broad policy or commitments concerning the use of Landsat data can be made, the extent of these limitations and their effect upon the programs which would use the data must be well understood. This program offers insight into some of these issues.

PROGRAM

BACKGROUND

As part of its Section 208 Areawide Water Management Program, the Toledo Metropolitan Area Council of Governments contracted with ERIM to prepare a base of land cover/use data which met stringent requirements for input to models used to evaluate nonpoint sources of pollution. The resulting data base includes 35 categories of dominant land cover/use with 12 associated physiographic and cultural features, detailed watershed and political boundaries, and other information. The land cover/use information was derived from medium scale aerial photography and checked for accuracy. This data is formatted in uniform 4 hectare cells (200 X 200 meters) on UTM projection and stored on a digital tape.

ERIM also used the same photointerpretation method to provide the Corps of Engineers Lake Erie Water Management Study a similar data base for the entire Lake Erie Basin, although at a less intense sampling level.

CONCEPT AND GOAL

The TMACOG data base, because of its strict geographic digital format, provides a unique opportunity to assess Landsat data by overlaying and comparing the satellite and the photointerpreted information. ERIM's Earth Resources Data Center (ERDC), with assistance by Corps personnel, is being used to classify the Landsat data. The interpreted Landsat data will then be merged with the photointerpreted data on a point by point basis. Statistical comparisons between the two data sets will be generated to establish the geometric and interpretation accuracy of the Landsat data as an input to water quality models used for nonpoint pollution studies.

LANDSAT PROCESSING

The Landsat data is being processed in the ERDC facility at ERIM using the satelite's multi-date capability to maximize the number and accuracy of land cover categories. To carry out this effort, a spring (May 10, 1975) and summer (August 8, 1975) scene was selected to coincide as nearly as possible to the photographic derived data base (1975). The Landsat scenes were first resampled into a 50-meter cell UTM projection where they were merged to create an 8-band data file. The data in this format is processed by a standard maximum liklihood algorithm using training sets established from the photography. This processing is now in progress and will result in a digital land cover file in the UTM projection where they were merged to create an 8-band data file. The data in this format is processed by a standard maximum likelihood algorithm using training sets established from the photography. This processing is now in progress and will result in a digital land cover file in the UTM projection.

To facilitate quantitative comparisons between the Landsat and photo derived data bases the photo data base will be resampled into a 50 meter cell and merged with the Landsat file. This will allow correlation of the Landsat data not only with the dominant landcover/use but also with the associated features, as interpreted from the photography. A more realistic and precise evaluation of the accuracy of the Landsat classification will result.

DATA ANALYSIS

The classified and resampled Landsat tape and the existing photo-interpreted data tape will then be merged and compared statistically. For purposes of this study, the photointerpreted and Landsat data will be treated as two or more channels of multispectral data, and modules will be run to compare them, prepare statistics, and provide confusion matrices between classes. As a minimum, landcover area statistics over major watersheds will be compared, and confusion between major classes will be calculated, along with a comparison of the photo and satellite identification of each cell. Other comparisons will also be developed. The results of this processing will be presented in various graphs, charts, and tables in the final report, along with the details of how each was obtained.

SANTA CRUZ COASTAL PROCESSES
SANTA CRUZ, CALIFORNIA

GEORGE W. DOMURAT

U.S. Army Corps of Engineers
San Francisco District

Santa Cruz is located on the northern coast of Monterey Bay, about 65 miles south of San Francisco and 14 miles north of Moss Landing, California. Santa Cruz is a recreational resort area, known for its fishing, boating, golfing, swimming and surfing. Seasonal climatic changes affecting local coastal processes impact directly on the economics of this area.

Aerial color photography is used to qualitatively describe various coastal features and processes along this reach of high-energy coastline. Seasonal shoreline changes, harbor shoaling, effects of groins, wave refraction and reflection and sediment transport are a few of the topics presented in this poster paper.

The presentation will attempt to show how this remote sensing tool can be used to gain a better understanding of beach erosion/accretion processes for a site specific area.

THE APPLICATIONS OF COLOR PHOTOGRAPHY FOR REGULATORY FUNCTIONS, PLUS...,

Paul E. Dimock
Kevin Pierard

U. S. Army Engineer District, Chicago
Chicago, Illinois

THE APPLICATIONS OF COLOR PHOTOGRAPHY FOR REGULATORY FUNCTIONS, PLUS...,

A ruling by the District Court of the District of Columbia expanding Corps regulatory authority came after concern was expressed over the destruction and degradation of unregulated tributaries to navigable waters, and also degradation and destruction of lakes, isolated wetlands and potholes. The ruling gave the Corps of Engineers jurisdiction over waters other than navigable waters of the United States.

Since we were now to regulate thousands of miles of additional waterbodies, there was a need for baseline data on these waters. Among items of interest were the characteristics of the waterway, number and type of existing structures on or in the waterway, type and extent of wetlands and the type of vegetation associated with the waterway and wetland.

METHODS OF ACQUIRING DATA

There were three reasonable methods of acquiring the data. These methods were field inspections, remote sensing and using existing data. After exploring the possibility of performing on site inspections it was easily seen that it would take a tremendous effort and use of manhours to perform the work in a timely manner. Remote sensing would give the desired results but appeared to also be extremely costly. Using existing data was the least costly method; however, a great deal of time would be spent gathering such information. Source of information includes U.S.G.S. quadrangle maps, county maps, county and State publication. Quick checks proved the information would be incomplete. The type, quantity and quality would not fulfill our need and requirements. The data was either too old, lacked detail and, at times, was not available for all waterbodies. For these reasons, it was decided to explore the possibilities of remote sensing in more detail.

SELECTION OF METHOD

Four particular methods of remote sensing were considered: landsat imagery, high altitude photographs, low altitude photographs and infrared photography. The more sophisticated and exotic types of remote sensing such as radar, microwave etc., were considered inappropriate for the needs. After an initial look at satellite imagery, it was eliminated from consideration because it lacked the detail we desired and also it was more costly than the other alternatives. High altitude photography also lacked the detail, although it appeared to be the least costly method available. Infrared photography seemed ideal for some of the information we needed, however ideal times for gathering the information were limited and would not permit covering all of the area in a timely manner without excessive cost. Low altitude photography was best suited for all the types of information we needed even though it was more costly due to the amount of film and processing needed to cover the area required. Color photography was eventually selected over black and white even though added costs were incurred. It was determined that color photography allowed for more precise interpretation than black and white.

Determining specific criteria and allowances was our next task. This was to insure that all the information was gathered in the most timely manner. Knowing we could not cover all the waterways within our boundares, we selected the primary tributaries to major waterways. This initially represented about 3,000 miles. To enable us to identify almost all structures a scale of 1 inch = 500 feet was selected. The area was to be flown in the spring when the ground was free of snow and leaves were not yet on the trees, it was also to be flown when there was no cloud cover.

HOW THE PRODUCT WAS APPLIED

The photographs are used by both field and office personnel. Other uses include the preparation of environmental assessments. The surrounding topography, land use, drainage characteristics, vegetation types, animal habitat and safety factors can be gathered from the aerial photographs.

Some jurisdictional determinations are also made, especially in the determination of adjacent wetlands. Wetland identification, including size, vegetation types, and values, can be accomplished using the aerial photos.

Some project impacts can be addressed, such as, downstream erosion or siltation problems due to channelization and stream coarse modification projects; impediments to navigation and possible conjestion of waterways can be identified; the cumulative impact of projects can also be identified and projected.

Field personnel use the photos to eliminate some on site inspections. When discussing proposed projects with applicants, many on site inspections are not necessary for the same reasons.

The photographs have been very useful at public hearings. The public, in general, can look at the area in respect to the surrounding community, or area. This is not easily done from the ground.

One of the most useful aspects of the photos is the elimination of field inspections and identification of the area where an on site inspection is required.

Many inquiries are received each day from individuals, as well as local and State agencies on whether or not a particular project will require a permit. In many cases, after referring to the aerial photos a determination can be made eliminating costly and time consuming field investigations.

In the area of enforcement, the aerial photos can clearly establish a date at which no work had been done prior to the Corps having jurisdiction. The photos are also effective in supporting our position in a court of law.

OTHER USES

Our photos are also used by other branches in the Corps as well as other agencies, on the local, State and Federal level, and by private citizens clubs and organizations.

The Environmental Resources Branch of the Corps uses the photos for interpretation of land use, to determine soil types, drainage pattern and erosion problems. They also use the photos to determine the geology of an area, vegetation types and wildlife habitat.

The Plan Formulation Branch of the Corps uses the photos as a basis for mapping and for alternative project design. They also use them to determine the environmental character of the area and for locating buildings in the floodplain.

The photos are used by the Floodplain Management Branch to locate property and structures in relation to the floodplain, to determine the "roughness factor" of an area and to identify other sources of flooding, such as, tributaries. They also help establish drainage area, wetlands and natural ponding areas.

Office of Counsel has found the photos are useful for evidence of documentation of illegal activities and to reinforce the testimony of witnesses by the Corps' Office of Counsel.

Another use of the aerial photos is by the Economics Branch of the Corps. The photos help them establish adjacent wetlands, drainage area, vegetation types and land use. They also use the photos with topographic maps to make field checks easier and to determine cost estimates for major flood damage by showing structures in the floodplain.

The U. S. Environmental Protection Agency uses the photos to delineate wetlands and determine cumulative effects of projects on land use.

The U. S. Fish and Wildlife Service uses the aerial photos in the regulatory review of permit applications to tell where a project is and what is already in the area. They also aid in determining vegetation types and habitat.

State and local highway officials have used the photos for right of way and corridor selection. Developers, professional people, private citizens, clubs and organizations also use the photos for many reasons because they are easy to understand and they show detail.

RESULTS, CHANGES, SUGGESTIONS

We have been extremely pleased with the total usage of the products. The wide and varied uses and applications have exceeded our initial expectations. One thing we have found useful is the cross referencing of the photographs and the U.S.G.S. Quadrangle maps for easier location of a specific area.

COST EFFECTIVENESS

While exact figures would be hard to determine, it is certain that for regulatory function purposes alone the cost of the photography would be offset by not requiring on site inspections within 5 - 7 years.

Adding the additional uses by the Corps this frame is significantly reduced, and further taking into consideration the savings realized by other Federal, State, and local agencies, there is added overall benefit in the tax dollars spent.

SNAKE RIVER RIPARIAN VEGETATION MAPPING

S. Holmes, R.K. Dodge
U.S. Army Corps of Engineers-Portland District
Portland, OR

ABSTRACT

Fish and Wildlife Section requested determination of the amount and distribution of vegetation along the Snake River. This was completed utilizing Walla Walla District black and white photography.

The goal of this project is to determine zones of riparian vegetation and measure areal extents along the Snake River. Variable scale black and white photography was obtained from Walla Walla District for analysis. Photographic scale averages 1:12,000.

Individual photos, illustrating zones of particular vegetation types were selected to provide ground control. The area of each selected photo was located in the field and vegetation types verified by the project photo-interpreter and two ecologists. Photos were then mosaiced in consecutive sheets of descending river miles and vegetation class boundaries drawn on clear mylar. Determination of the areal extent of each discrete zone of vegetation and precise photo scaling were done with facilities at Oregon State University, Department of Geography.

BONNEVILLE DAM SECOND POWERHOUSE PHOTOGRAMMETRIC CROSS-SECTIONS FOR EXCAVATION CONTRACTOR PAYMENTS

R. K. Dodge, S. Holmes
U.S. Army Corps of Engineers - Portland District
Portland, OR

ABSTRACT

Photogrammetric measurements from monthly aerial flights were used to determine earth volumes at Bonneville Dam Second Powerhouse for excavation contractor payments.

The Portland District monitors the on-going activities at the Bonneville Dam Second Powerhouse construction project through monthly aerial flights. In addition, this aerial photography is used as a basis for photogrammetric measurements in order to determine volume removal at the powerhouse site for ultimate contractor payments.

Black and white photography at two scales is obtained around the first of every month by an aerial contractor. High altitude imagery at 1:24,000 provides a general overall view of the project and is utilized for enlargements to show certain areas or activities in progress. In addition, low altitude imagery at scale 1:6,000 is obtained in order to show construction activities in greater detail as well as provide for possible photogrammetric measurements.

During the period from May 1977 to September 1978 photogrammetric cross-sections were taken from these monthly flights for pay quantity determination. Diapositives of the stereo pair(scale 1:6,000)centered on the large second powerhouse excavation site, were prepared and set up on a first order Wild A-10 Stereoplotter. A gridded manuscript at scale 1" = 100' showing specific cross-section alignments and plotted positions of surveyed control points was also prepared. Using this manuscript, the stereopair or "model" was oriented to a ground control system so that precise horizontal and vertical data could then be obtained from any image point in the stereo pair.

Once a "model" was oriented, elevation data was obtained photogrammetrically along the specific alignments portrayed on the manuscript through a digitizing process. The stereoplotter is equipped with rotary encoders along its three axes of movement so that electronic pulses become the precise signal or indicator of linear movement in the three diminsional stereomodel. These pulses are counted by a three axis digitizer which converts the signals into a numeric distance moved in terms of a preset origin. This data is recorded on a 9-track magnetic tape for ultimate processing or plotting on an off-line computer.

The powerhouse excavation required approximately 40 cross-section alignments averaging 1800' long, spaced in parallel 50' apart. By recording or digitizing points along each alignment where a significant change in terrain relief was detected, the stereoplotter operator obtained a high density of elevations which provided an accurate model of the ground. These data may be later provided in the form of cards, printouts, plan and profile plots or may be stored on tape and disc for later processing. The Bonneville Second Powerhouse data were provided on "earthwork" cards for subsequent insertion into a pay quantity determination computer program. By comparing data from a digitized model with data recorded from photography flown one month earlier, an accurate measurement of the amount of earth removed by the excavation contractor may be obtained.

This procedure for obtaining pay quantities is very cost effective in comparison with other methods of obtaining the data, namely counting truck loads of material or taking the cross-sections by field surveys. Photogrammetric cross-sections are taken from a photograph where all terrain conditions are recorded instantaneously in one image. Contrast that with the many days of work required of a survey crew operating in a dangerous environment where the terrain is constantly changing. In addition, an area the size of the Bonneville Second Powerhouse excavation can be measured by one stereoplotter operator in two to three days compared to two to three weeks for a five man survey crew. The procedure is highly accurate,providing timely information in a consistent manner; consequently, it has been accepted by both government and the contractor as the basis for contract payments.

ENVIRONMENTAL ANALYSIS OF THE DAN RIVER BASIN

Coleman Long
Dave Frankensteen
Ben Kutscheid

U. S. Army Engineer District, Wilmington
Wilmington, North Carolina 28402

1. INTRODUCTION

The Dan River Basin Model Study was initiated through the joint efforts of the Wilmington District, South Atlantic Division, and the Office of Chief of Engineers of the Corps of Engineers. The initial study goals were to:

(1) Meet contemporary environmental quality planning standards.

(2) Test the use of automated spatial data management and satellite imagery in an ongoing study.

2. DATA COLLECTION AND STORAGE

The definition of environmental quality conditions, needs, and opportunities requires large amounts of information regarding natural resources and land-use patterns. The preparation of the data base for the Dan River Basin involved collection, reformatting and computer storage of physical and biological information. Land cover data was obtained from LANDSAT imagery with the help from NASA's Earth Resources Laboratory and Bendix Corporation. A color-coded map and computer compatible tapes were the products.

The land cover tapes were translated into the data stage system with no additional formatting. Other data components such as soils, geology, climate, and bottomlands had to be mapped, encoded and converted to grid cells before they could be stored into the system. Topographic information (slope, aspect, and elevation) was produced by interpretation of digitized 1:250,000 contour lines. All data components were merged into a multivariable grid cell data bank for analysis purposes.

3. METHODOLOGY

The relationships that exist between physical and biological elements can be used to predict environmental conditions and values. For large areas such as the Dan River Basin, however, the collection and handling of these elements can be exhausting using conventional techniques. Using an automated spatial data management system that includes attractiveness modeling, statistical interpretations and similarity comparison, we have been able to store and manipulate large quantities of data. Predictions for environmental conditions, land use changes, and project impacts can now be made reasonably quickly.

Computer software (RIA package) was obtained from HEC to compile and analyse data through various modeling techniques. The RIA package also included a mapping program that plots grid cell maps using shading patterns and outlining.

A cluster program was obtained to determine similarities for various physical and biotic characteristics. Other programs were created or modified from existing programs to complete the various studies that were initiated. Such programs include an evapotranspiration package and a habitat diversity index package.

4. RESULTS

Several individual studies were completed using various modeling techniques that access the computerized data bank. They address aquatic and terrestrial conditions in terms of wildlife habitat, ecological classification, stream quality, and productivity. Each study used existing physical and biological data from the data file to project across the basin.

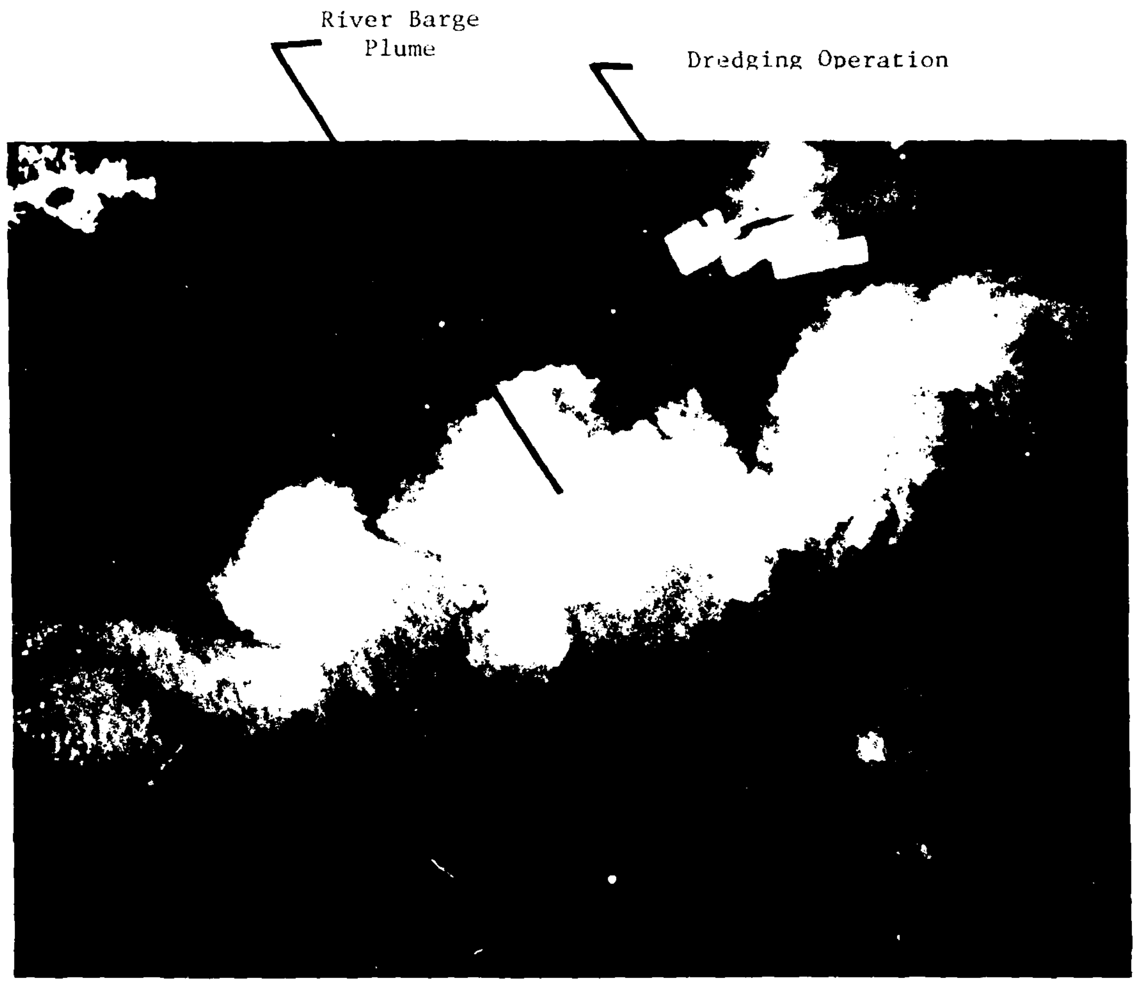
The results of these studies were used to define conditions, determine values and address environmental quality planning objectives for the basin. They were also used to determine impacts on proposed alternatives from a basin perspective.

ANALYSIS OF RIVER TURBIDITY PLUMES USING AERIAL PHOTOS

James P. Scherz
Professor of Civil and Environmental Engineering
University of Wisconsin
Madison, Wisconsin

Robert Whitting
U. S. Army Engineer District, Saint Paul
Saint Paul, Minnesota

Terry Teppen
Environmental Protection Agency
Minneaspolis, Minnesota



AERIAL PHOTOGRAPH ILLUSTRATION
TYPICAL RIVER TURBIDITY PLUMES

INTRODUCTION

This report relates to the use of aerial photos in a comprehensive study of turbidity plumes on the Mississippi River south of Saint Paul, Minnesota. In July 1977, the U. S. Army Corps of Engineers in conjunction with the EPA and state agencies and university personnel from Minnesota and Wisconsin made an extensive study of the turbid plumes caused by dredging operations in the river and of those caused by normal river barge traffic. Dozens of water samples were taken by several boats on July 25 and 26. Prior to each sample set, the boats were positioned by an observer with a radio in a photographic plane. At the precise time the samples were collected, simultaneous color and color-IR photos (35mm) were taken of water conditions during that sampling event.

These photos were later analyzed on a color microdensitometer. With the use of the water samples to calibrate each photo, turbidity maps were made of the plumes.

DISCUSSION

Site Location

The location of the study was about 7 miles SE of Saint Paul, Minnesota, near Lower Grey Cloud Island. See Figure 1. There the bottom muds were dredged up in the river channel (at the dredge site), loaded onto barges and deposited upstream on an island called the disposal site. Figure 2 shows a map of the dredge and disposal sites and surveying measurements which were used as photographic control for making the turbidity maps.

Field Work

On 21 July 1979, dyes were released at the dredge and disposal sites and aerial photos were taken over an hour period to ascertain the precise direction and speed of the river current. Various altitudes and photo exposures were tested to optimize the photography of the river water. Radio communications between the airplane observer and the boat crew were also checked at that time. The photos were developed and checked prior to the first day of sampling at the disposal site.

On 25 Fuly, 5 sets of water samples and aerial photos were taken at the disposal site between 2:30 pm and 5:39 pm. Barges passed by the site at 2:03 pm, 3:28 pm and 3:35 pm. Figure 3 shows photos of the disposal site. The highest surface turbidity recorded at the disposal site was 25 JTUs:* Figure 4 shows a barge passing near the disposal site.

---

*The water quality parameter of turbidity can be measured by various techniques. One technique gives turbidity readings in JTUs, another in FTUs (which are about the same as JTUs). A third techniques gives turbidity in NTUs, which are usually higher than JTUs.

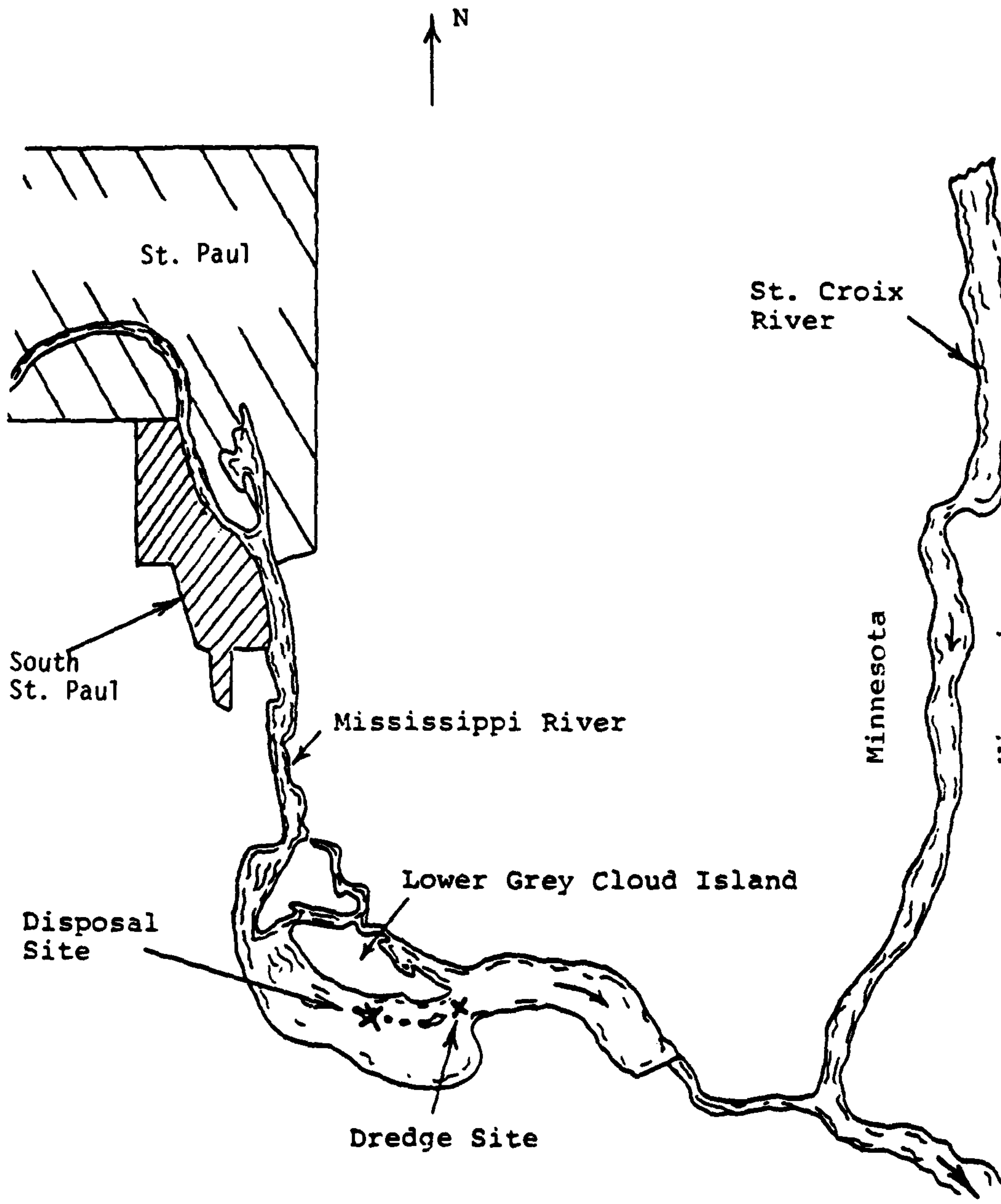


Figure 1. Map showing location of study site

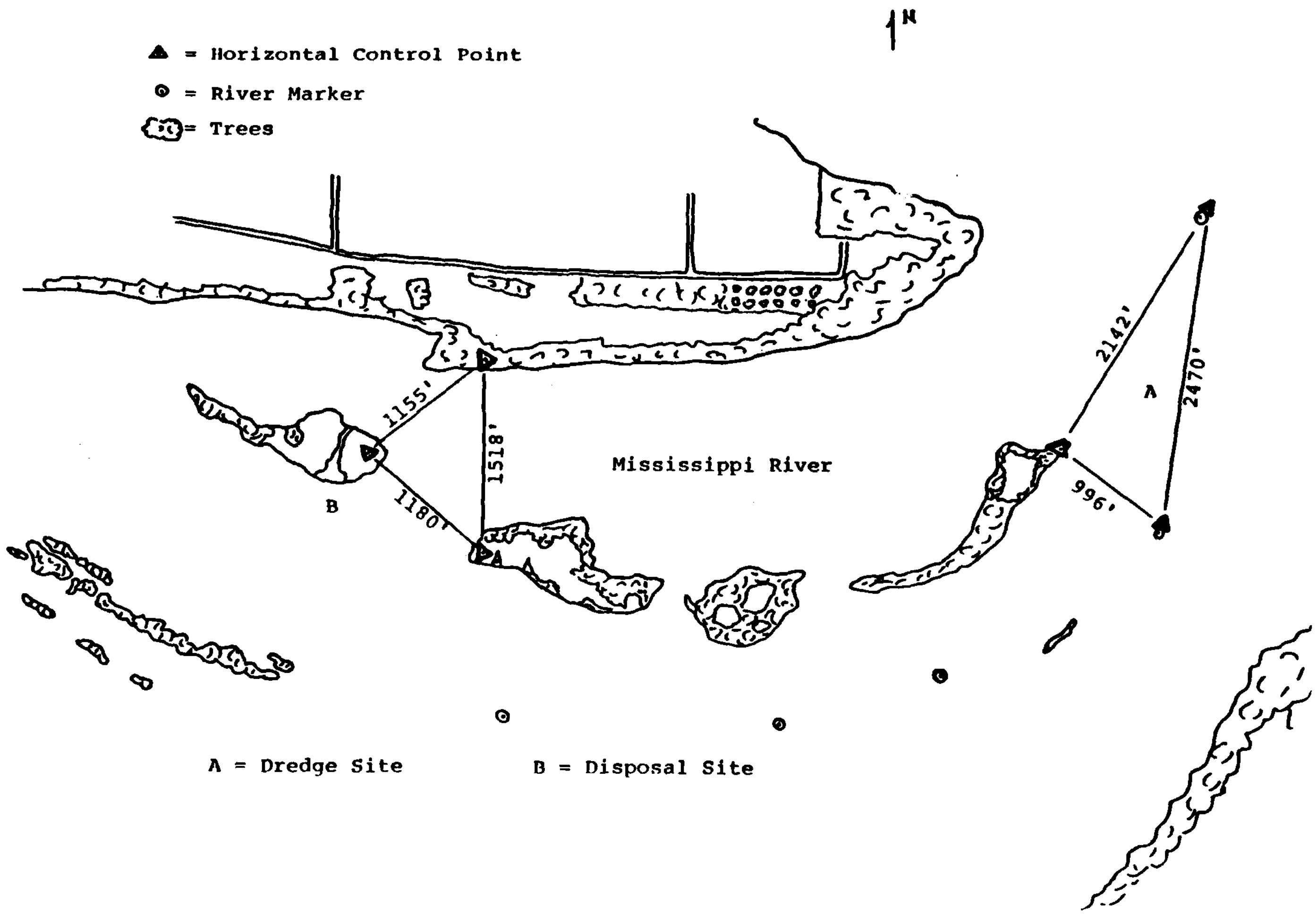


Figure 2. Index Map Made from Indicated Ground Control Distances

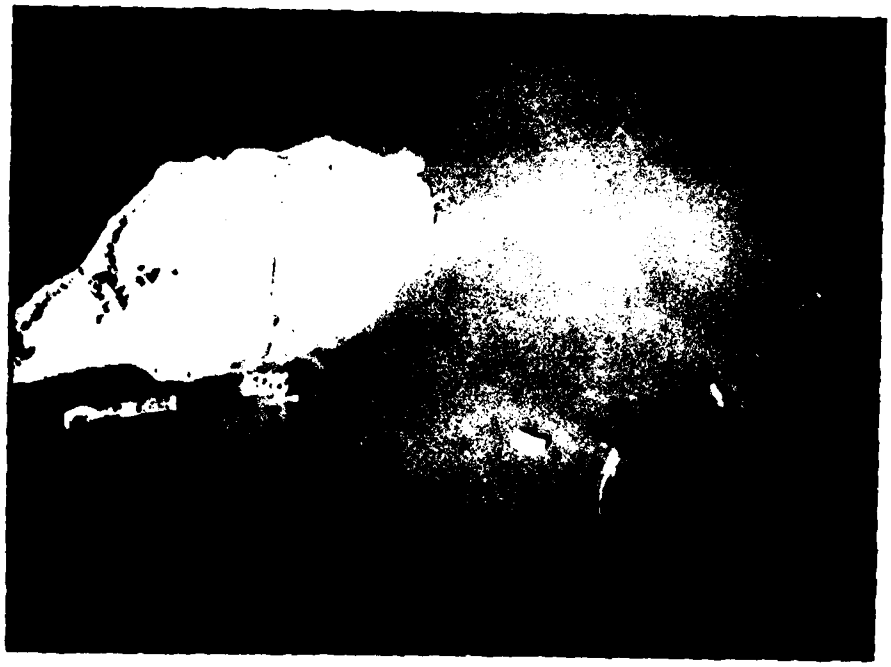


Figure 3. Disposal Site

Figure 4. Barge Passing Near the Disposal Site

Figure 5. Dredge Site

Figure 6. Plume from a Barge that Passed Near the Dredge Site

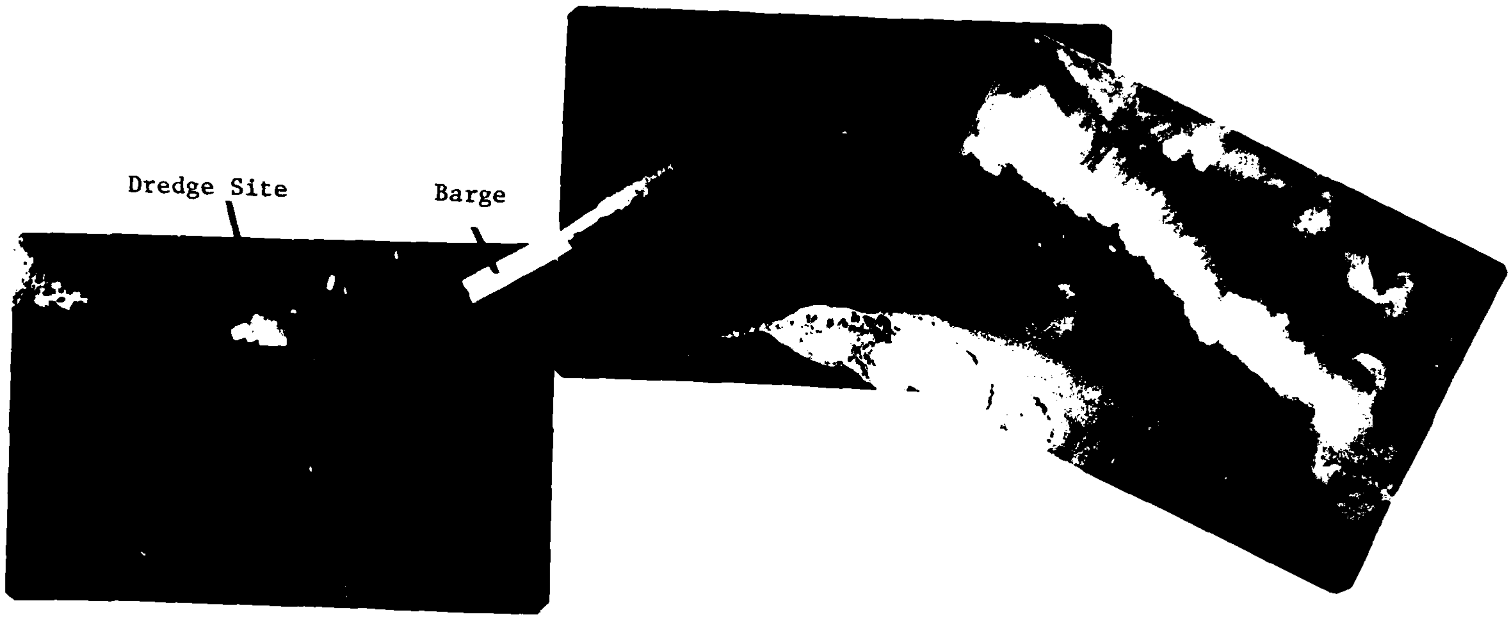


Figure 7. Color IR photos of barge passing the dredge site, 3:16 pm, 26 July 1977

On 26 July, five sets of water samples and photos were taken at the dredge site between 9:39 am and 3:54 pm. A barge passed the site at 3:18 pm. Figure 5 shows photos of the dredge site. The highest surface turbidity reading at the dredge site was 20 JTUs.

Figure 6 shows a plume caused by a barge that passed near the dredge site. Figure 7 shows a photo of the barge near the dredge site at 3:16 pm on 26 July. The highest turbidity reading near the barge plume was 265 NTU (about 120 JTU equivalent). A water sample was collected near the barge plume for settling tests. Another water sample was collected in a nearby algae bloom to assure that the difference between muddy water and algal water could be determined by analysis of spectral fingerprints from the aerial photos. They could.

<u>Settling Tests</u>

The samples collected from near the barge plume were shaken up and placed in a 2 ft. deep column. Settling tests were then run on this sample by checking the turbidity of the water at mid-point of the column at different times. The results of this test are shown in Figure 8. The initial turbidity of the sample was 40 FTU (approximately equal to JTUs). After 30 minutes, a turbidity of 12 was recorded. A residual turbidity of 7 JTUs existed after 2 hours and about 6 JTUs after 4 hours. With barges passing on an average of about every 2 to 4 hours, one would expect a background turbidity in the river of at least as high as 6 or 7. This was what it was.

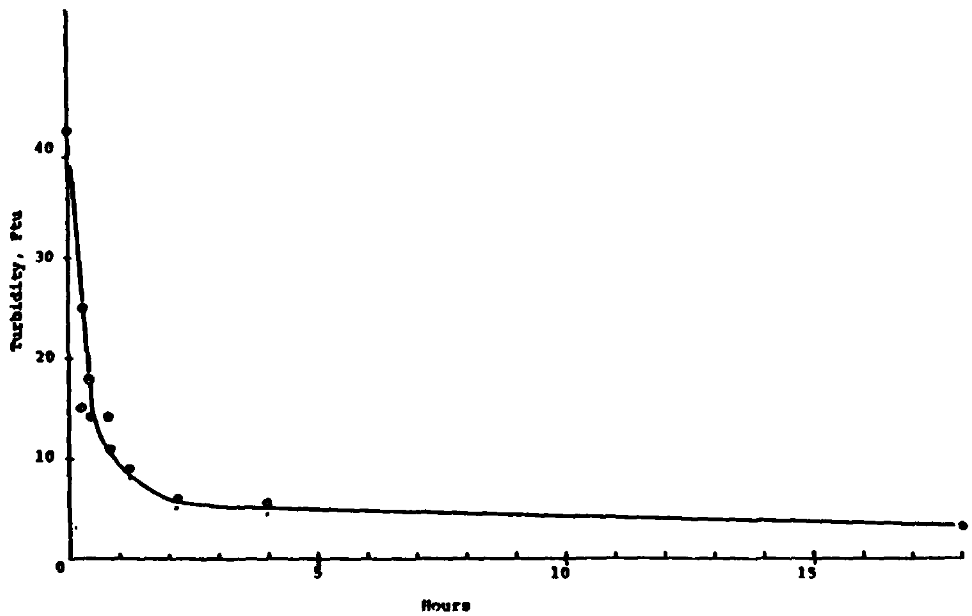


Figure 8. Settling Test for River Water with Suspended Bottom Muds

Light Penetration Analysis

The light penetrates (and returns to the camera) only to a certain depth into the water. This depth depends on the turbidity. The Secchi Disc Reading is a means of measuring this depth. The Secchi Disc is a white disc lowered until it disappears. This depth is called the Secchi Disc Reading. Figure 9 shows the relationship between Seechi Disc Readings and turbidity. This curve is useful in ascertaining the depth to which the aerial photos penetrated into the river for various surface turbidities.

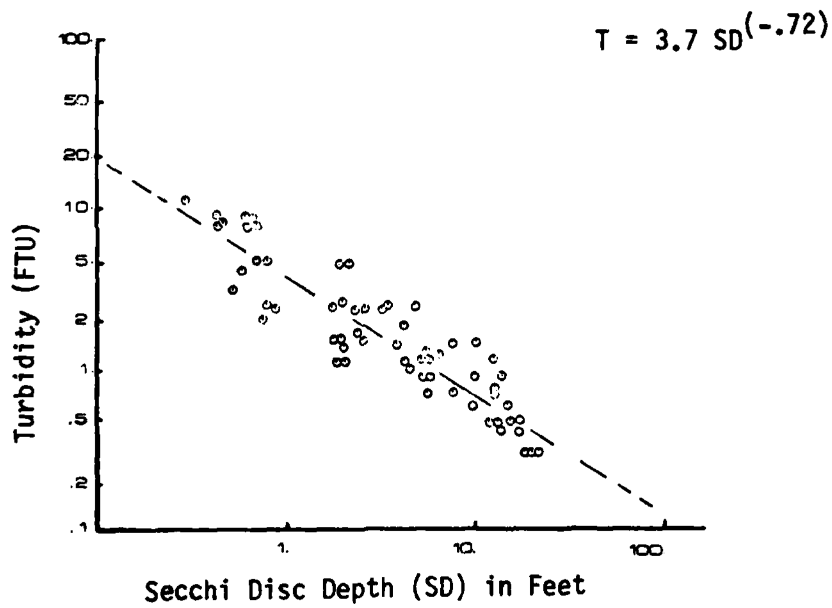


Figure 9. Turbidity versus Secchi Disc Readings
(From Scherz et al., September 1977)

Lab Analysis of Aerial Photos

The aerial photos were analyzed with a color microdensitometer. The color and color IR photos were analyzed at wavelengths of 0.45 microns (blue), 0.55 microns (green), and 0.65 microns (red). When color IR photos are analyzed there is a shift between analysis light and light that exposed the film. On the color IR photos, an analysis at 0.45 microns (blue) corresponds to the green color that exposed the film. Similarly, analysis at 0.55 microns (green) and 0.65 microns (red) corresponds to exposing light of red and IR, respectively. The spectral fingerprints from analyzing the photos revealed that the algae bloom on the river nearby could be easily differentiated from the stirred-up bottom muds.* The analysis also showed that the red exposing light (0.55 microns on the IR or 0.65 on the color photos) gave good differentiation between very turbid and slightly turbid water and also gave values significantly above noise levels in the system.

Difference Between Laboratory and Airborne Reflectance

If a water sample is analyzed in the laboratory, the radiance from the water volume is V. See Figure 10. This can be compared to the radiance from a standard reflectance panel (P). The ratio of V/P is called Laboratory Apparent Reflectance (AP);

$$AP = \frac{V}{P} = \frac{\rho_v}{\rho_p} \qquad \text{(Equation 1)}$$

where ρ_v is the volume reflectance of the water and ρ_p is the reflectance of the panel.

There is a straight line correlation (on Log-Log paper) between turbidity and AP (and therefore ρ_v). See Figure 10. In Figure 10 white planes used to obtain the data for the lab curve had a reflectance of 0.39.

$$\rho_p = 0.39$$

So in Figure 10, $AP = \frac{\rho_v}{.39} = 2.56\ \rho_v$

When the water sample is in a lake and analysis is with an airborne sensor there are many noise factors added to the reflectance from the water (the radiance from the water volume in the field at boat level is called V').

---

*A spectral fingerprint for a water results when some function of reflectance is plotted against color of the light (wavelength).

One noise factor always present is the reflectance of the skylight from the surface of water. On windy days when there are rough waves and possibly white caps, some of the sun's energy might also be reflected from waves and foam. (However, care must always be taken not to include the area of <u>direct</u> sun glare or glitter that can be seen on sunny days reflecting from the water surface). The total energy reflected from the air-water interface is called S'. The total energy returning from the water (at boat level) is W'; W' = V' + S'. When a large field panel is used as a standard in aerial photographic work the energy at boat level that returns from the panel is P'.* As W' and P' travel upward to the aerial camera they are attenuated by the atmospheric transmittance T. Also an atmospheric backscatter signal (LA) is added. Let W" and P" be the final radiances from the water and the panel which read the airborne camera:

$$W'' = W'T + LA$$

$$P'' = P'T + LA$$

Let $AP'' = \frac{W''}{P}$

AP" is called the airborne apparent reflectance.

It can be shown that

$$AP'' = \frac{\rho_v}{\rho_p}\left(\frac{1}{K}\right) + \frac{S'T}{P''-LA}\left(\frac{1}{K}\right) + K-1\left(\frac{1}{K}\right) \qquad \text{Equation 2}$$

where K is determined by atmospheric conditions at the time the aerial photo was taken.

$$K = \frac{1}{1 + \frac{LA\ \pi}{\rho_p H'_o T}}$$

where H'_o is the total irradiance from sun and skylight that is available on a flat surface at the water level.

It can be seen from equations 1 and 2 that both AP and AP" increase as ρ_v increases. It is only the value ρ_v that relates to water quality and turbidity.

---

*If a white styrafoam reflectance panel is used in the field it has essentially the same reflectance (ρ_p) as the white $BaSO_4$ reflectance panel used in the lab. In both cases, $\rho_p = 0.39$.

Figure 10 shows theoretical AP" curves for assumed values of K and S'. When aerial film is used to obtain the AP" correlation curve (when a white panel is used), the curve appears higher and steeper than the theoretical curves. One reason for this is because when the photo has optimum exposure for water (a dark object) the white panel is over-exposed (the film is saturated with light) and the panel does not appear as light as it should. Grey panels would illuminate this problem. Figure 18 shows an actual AP"-Turbidity curve obtained with a white panel.

Obtaining the AP"-Turbidity Curves from Aerial Photos

Each roll of aerial film had a photographic step wedge exposed onto it. By analyzing the image of the step wedge (by use of a spectral microdensitometer) a film density versus relative exposure curve was producted. (This is called a D-Log E curve.) See Figures 11, 12 and 13.

The photo of the turbidity plume was then analyzed with the spectral microdensitometer. Density readings were taken in a grid fashion throughout the image of the water. Density readings were also taken on the images of the white panels appearing in the photo. These density readings were then corrected for lens falloff and for possible sun angle effects on the panel (if conditions warrented).* See Figures 14 and 15.

The X and Y positions of the control points, panels, shorelines and boats on the photo were also recorded during microdensitometer analysis. These locations as well as the corrected densities were then plotted on a transparent grid in their correct location. This density grid was then projected to a standard base map and manually transferred to this map.** (See Figure 16.) This density grid was then ready for tracing of turbidity "contours." But first it was necessary to ascertain which film densities correspond to the turbidity contours desired.

---

*The skylight surface reflectance also increases significantly for angles from the vertical greater than 40°. However, a normal or long focal length camera (as was used in this case) did not exceed angles from the vertical greater than 40°. If a wide angle lens had been used (which would sense angles from the vertical greater than 40°) then it would also have been necessary to consider corrections for skylight radiance from the water surface.

**The planimetric base map was made using conventional photogrammetric techniques. An aerial image showing 3 control points was projected to a grid where these control points were plotted to the desired scale. Then a rectified enlargement was made showing correct planimetric locations of the shoreline boats and other features. A tracing of this enlargement was the base map.

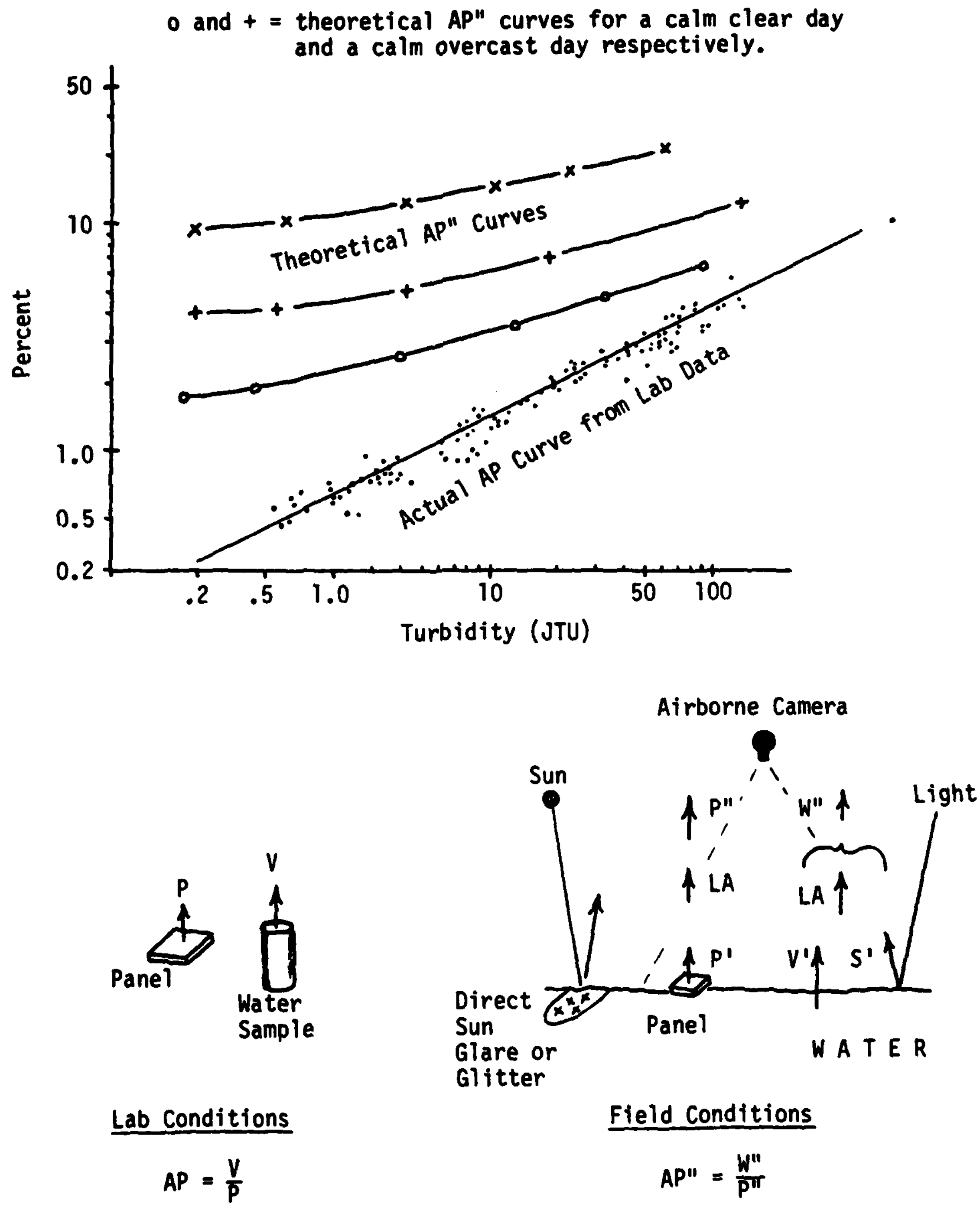


Figure 10. Curves Relating Turbidity to Actual Laboratory Apparent Reflectance (AP) and Theoretical Airborne Apparent Reflectance (AP")

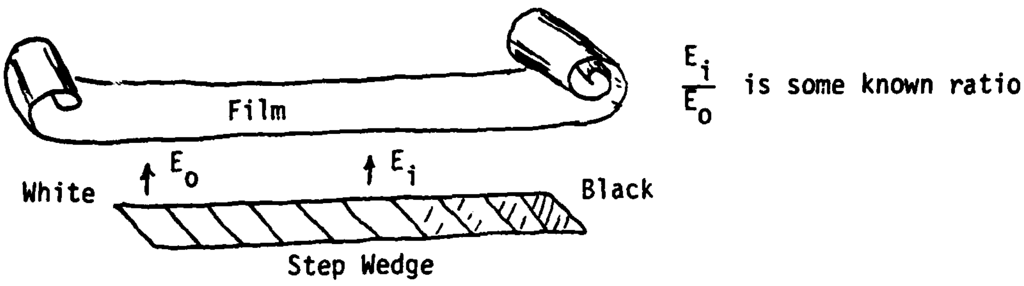


Figure 11. Exposing a Photographic Step Wedge onto a Film

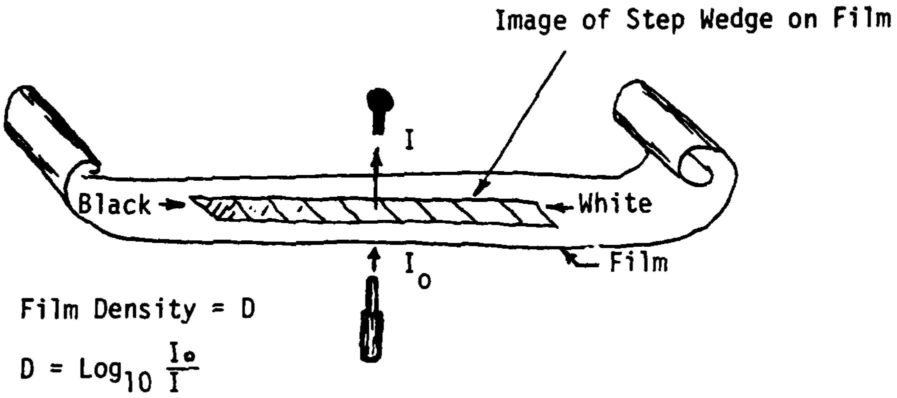


Figure 12. Analyzing the Step Wedge Exposed on a Film

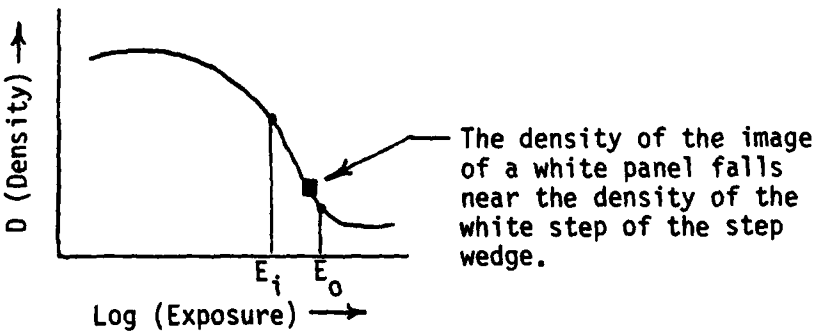


Figure 13. Typical D-Log E Curve for a Positive (Reversal) Film

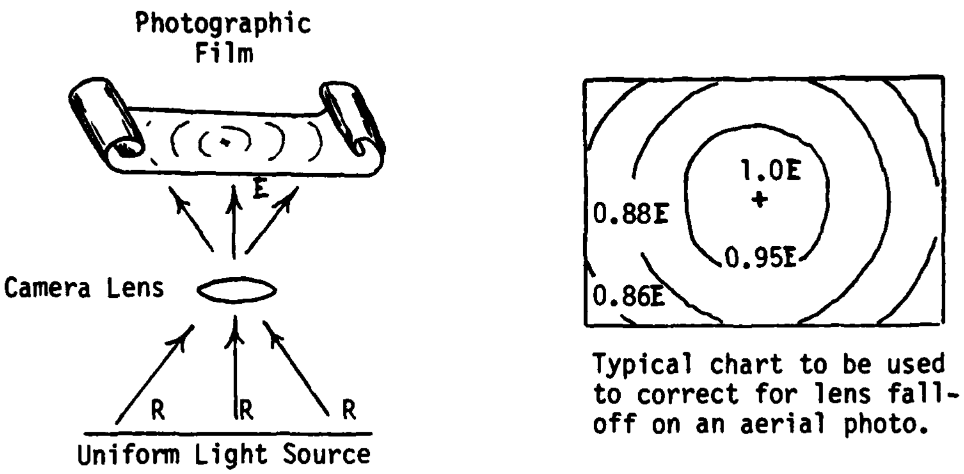


Figure 14. Lens Falloff Effects on an Aerial Camera

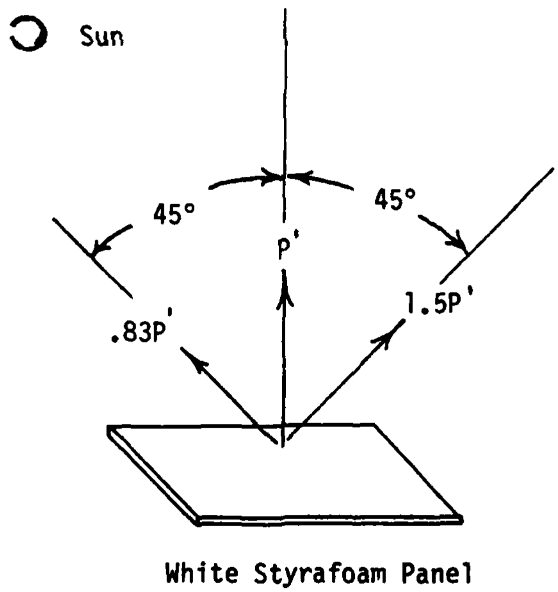


Figure 15. Typical Effects of Large Angles from the Vertical on the Observed Radiance from a White Styrafoam Reflectance Panel

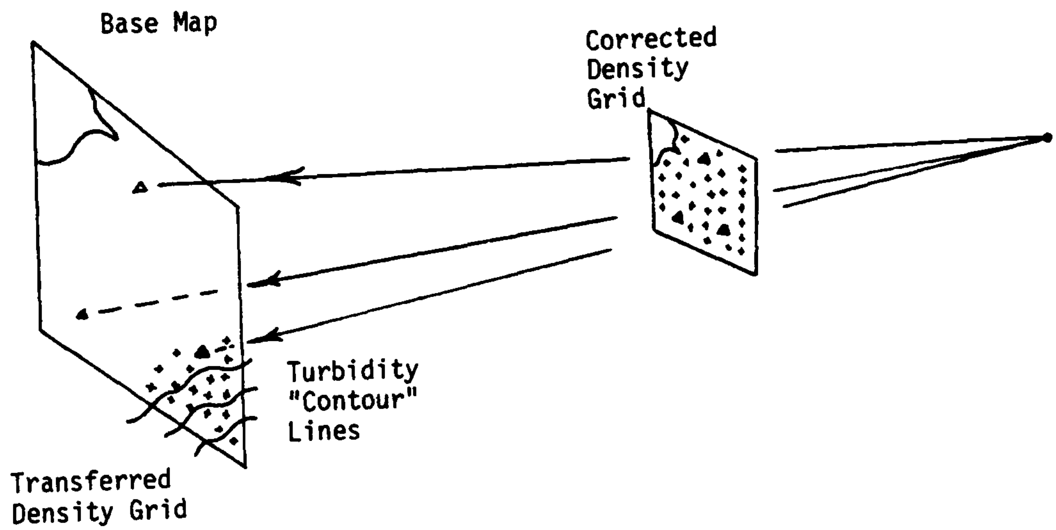


Figure 16. Projecting the Corrected Density Grid unto the Base Map

Obtaining Film Density Values Corresponding to Desired Turbidity Values

To obtain the turbidity "contour" lines from the density grid several curves were used.

First the density of the reflectance panel for that scene was superimposed on the D-Log E curve for that film. See Figure 17. This, then gave the exposure value E_p which correspond to the radiance from the panel (P") which exposed that part of the film. A value of 0.5 E_p gave a corresponding exposure of AP" = 0.5, etc. Such an analysis of various points resulted in a workable Density-AP" curve for that scene. See Figure 17.

The next step was to determine the location of the AP"-Turbidity curve for that scene. This was done by comparing the water turbidity values with the AP" of the water from the site where the sample was collected (the AP" values were determined from analysis of the film densities). Figure 18 shows an actual AP"-Turbidity curve for one of the scenes. The upper limit of the curves (a) could not be greater than 100%. The minimum level of the curve (b) was the minimum theoretical value of AP" expected on a particular day. For a calm clear day this minimum is about 0.5%. For a calm completely overcast day the minimum theoretical value is about 5.0%.

Once the correlation curve was positioned for that scene the desired turbidities to be contoured (such as 10, 15, 20 JTUs) were related to AP" values through the AP"-Turbidity curve. The resulting values of AP" were in turn related to film densities through the AP"-Density curve such as in Figure 17. Once the density were determined for the desired turbidity values, the density grid was then contoured.

Turbidity Maps

Figure 19 shows a turbidity map of the disposal site at 2:30 pm on 25 July 1977 (0.5 hours after a barge had passed). The maximum and minimum turbidities were 27 (JTU) and 7 (JTU) respectively. The area under the 10 JTU "contour" line was more than 55 acres. The area under the 15 JTU contour line was 17.1 acres.

Figure 20 shows a turbidity map of the dredge site and an appxomiate turbidity map of a plume caused by an approaching barge at about 3:15 pm on 26 July. Simultaneous samples were not taken in the barge plume. Sample data from the dredge site was "bridged" to the barge plume. At the dredge site at 3:15 pm it had been at least 6 hours since the last barge had passed. The maximum surface turbidity sample collected in the dredge plume at 3:15 pm was 10 JTUs. The area under the 10 JTU "contour" line at the dredge site was about 2.4 acres. The area under the 15 JTU contour line was zero. Upstream the background turbidity was as low as 5 JTUs.

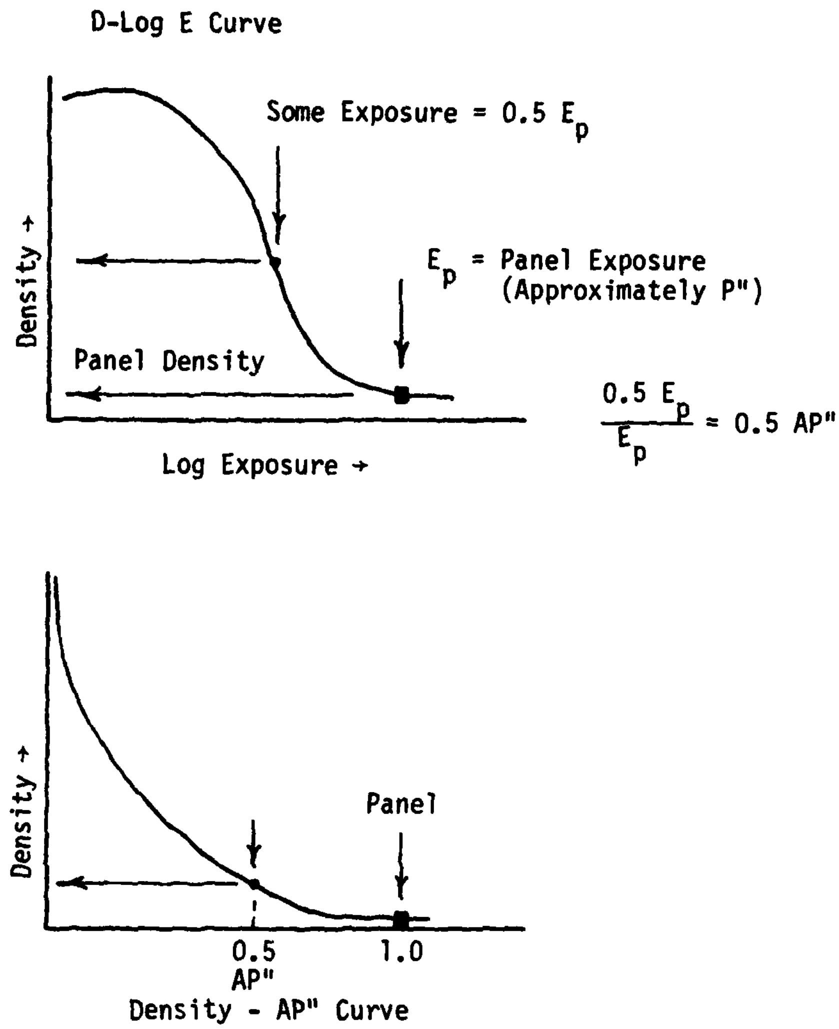


Figure 17. Obtaining Density-AP" Curves from Analysis of D-Log E Curve and Panel Density

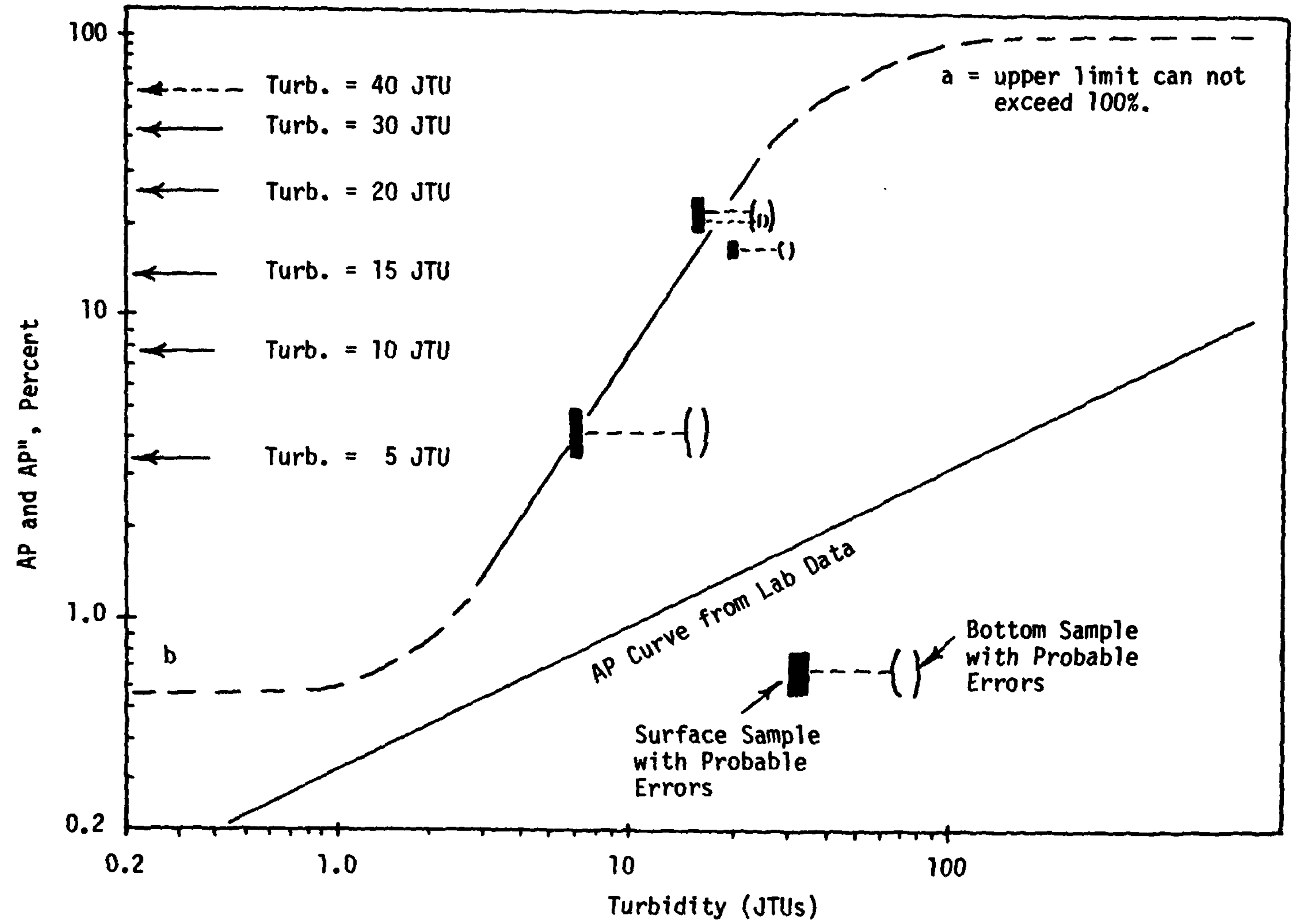


Figure 18. AP"-Turbidity Curvey for Photo of Dredge Site at 3:54 pm, 26 July
b = minimum value is skylight reflectance

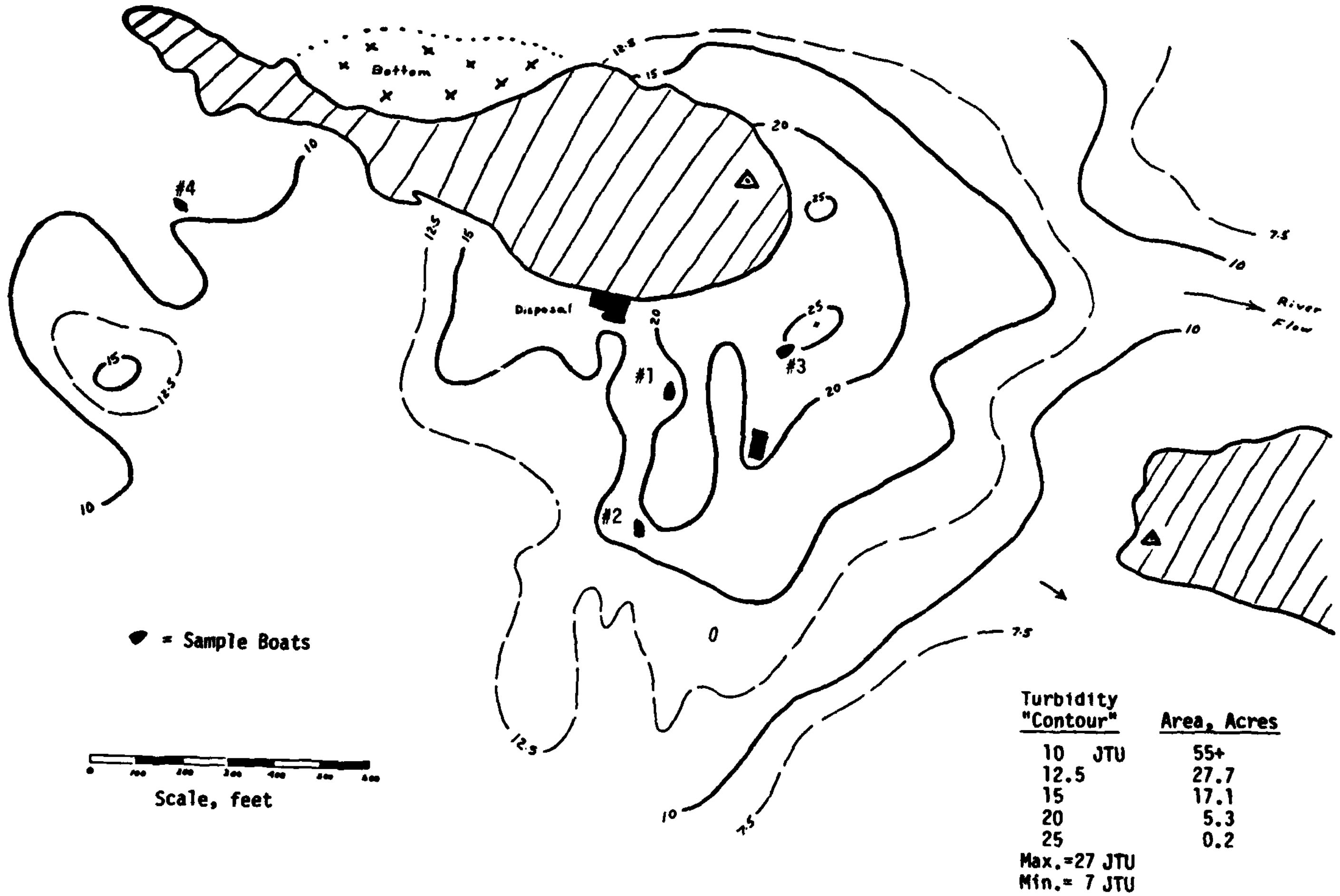


Figure 19. Surface Turbidity Map of the Disposal Site for 2:30 pm, 25 July 1979 (0.5 hrs after Barge Passage)

Area Caused by Dredge	Turbidity "Contour"	Area Caused by Barge
22+ acres	7.5 JTU	40+ acres
2.4	10.0	29.9+
0	12.5	12.5
0	15	6.7
0	20	2.9
0	30	1.9
0	70+	1.3

maximum = 11 JTU
minimum = 3 JTU

maximum = 80 to 120 JTU
minimum = 7 JTU

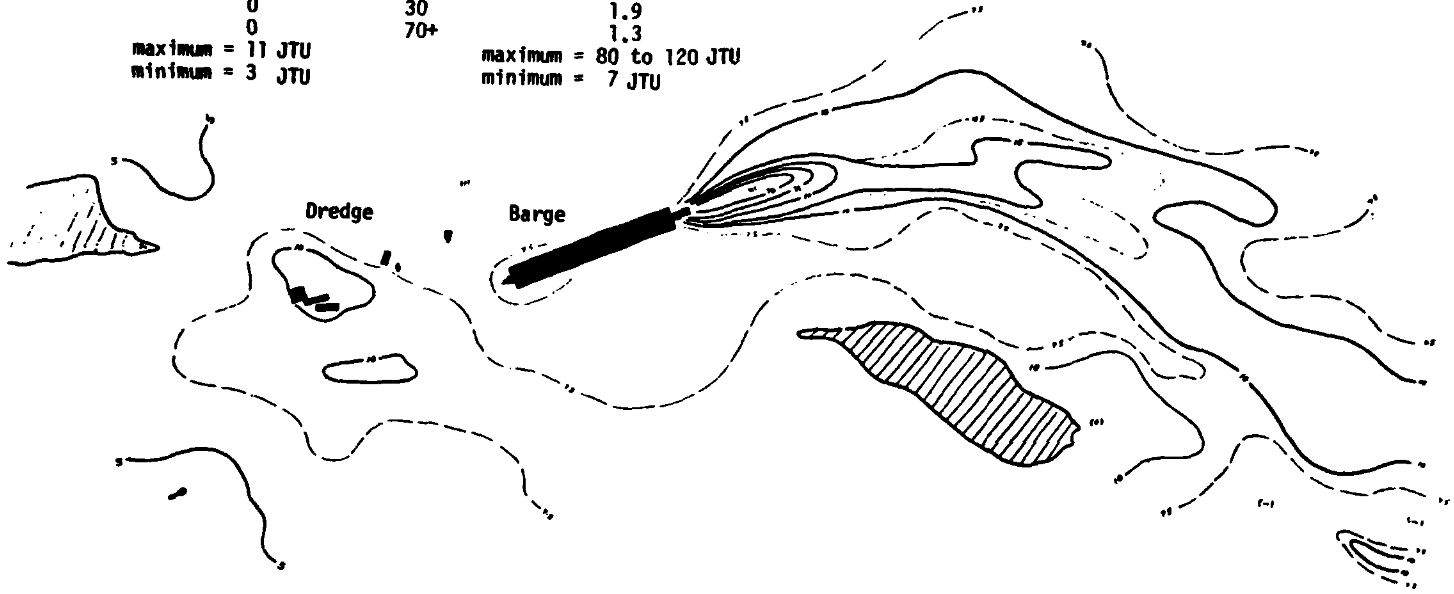


Figure 20. Approximate Surface Turbidity Map of Barge Approaching the Dredge Site at 3:15 pm, 26 July 1977. No simultaneous water samples.

A short distance away a barge is approaching. The maximum turbidity in the barge plume was more than 70 JTUs (the film saturates above this value). (See Figure 18.) In the barge plume the area under the 30 JTU contour is about 2 acres; the area under the 15 JTU contour is 6.7 acres, and under the 10 JTU contour, 30 acres with many more acres extending downstream.

Figure 21 shows the turbidity map of the dredge site at 3:54 pm on 26 July 1977 (0.5 hours after the barge shown in Figure 20 had passed). The maximum surface turbidity recorded from the surface water samples was 20 JTUs. The area under the 20 JTU contour line was 0.5 acres, under the 15 JTU contour line 5.5 acres and under the 10 JTU contour line more than 33 acres.

Figure 22 shows the increase in turbidity (maximum turbidity and area of turbidity contours) as the barge passed the dredge site.

Turbidity from Barges

From observations of Figures 19 to 22, it is obvious that the barge traffic causes high values of turbidity over large areas of the river. This turbidity stirred up by the barges lingers in the area until the bottom materials either settle or drift away. The current was very low at both the dredge and disposal sites (less than 30 ft/min or 0.35 miles/hour), so settling was the prime factor for clearing of the water after a barge has passed.

Figure 23 shows the surface turbidities of all water samples collected on 25 and 26 July plotted against time since last barge passage. There is indeed a straight line relationship between maximum turbidity and time since the last barge passed. This relationship looks very similar to the log-log plot of the settling test (from Figure 8) for water collected in the barge plume. (Figure 23 shows the settling test plotted on log-log paper.) Figures 23 and 24 further indicate that the maximum turbidity in the Mississippi River near the dredge site is primarily determined by the time since a barge passed.

CONCLUSIONS

It appears that the effect of the barge traffic on both the magnitude and area of turbidity in the river is many times greater than the effects of either the dredging or disposal operations.

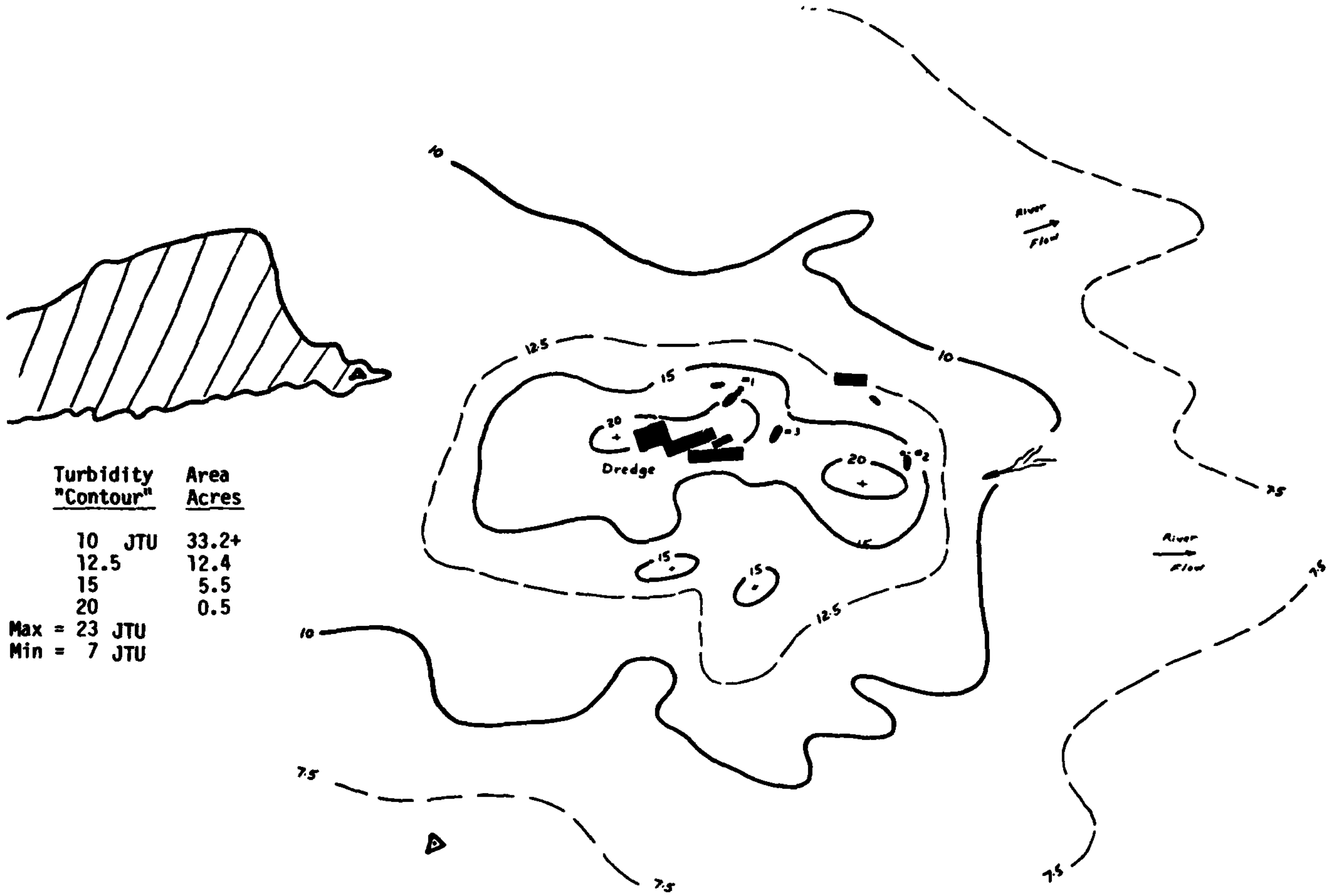


Figure 21. Surface Turbidity Map for Dredge Site at 3:54 pm, 26 July (0.5 hrs after Barge Passage)

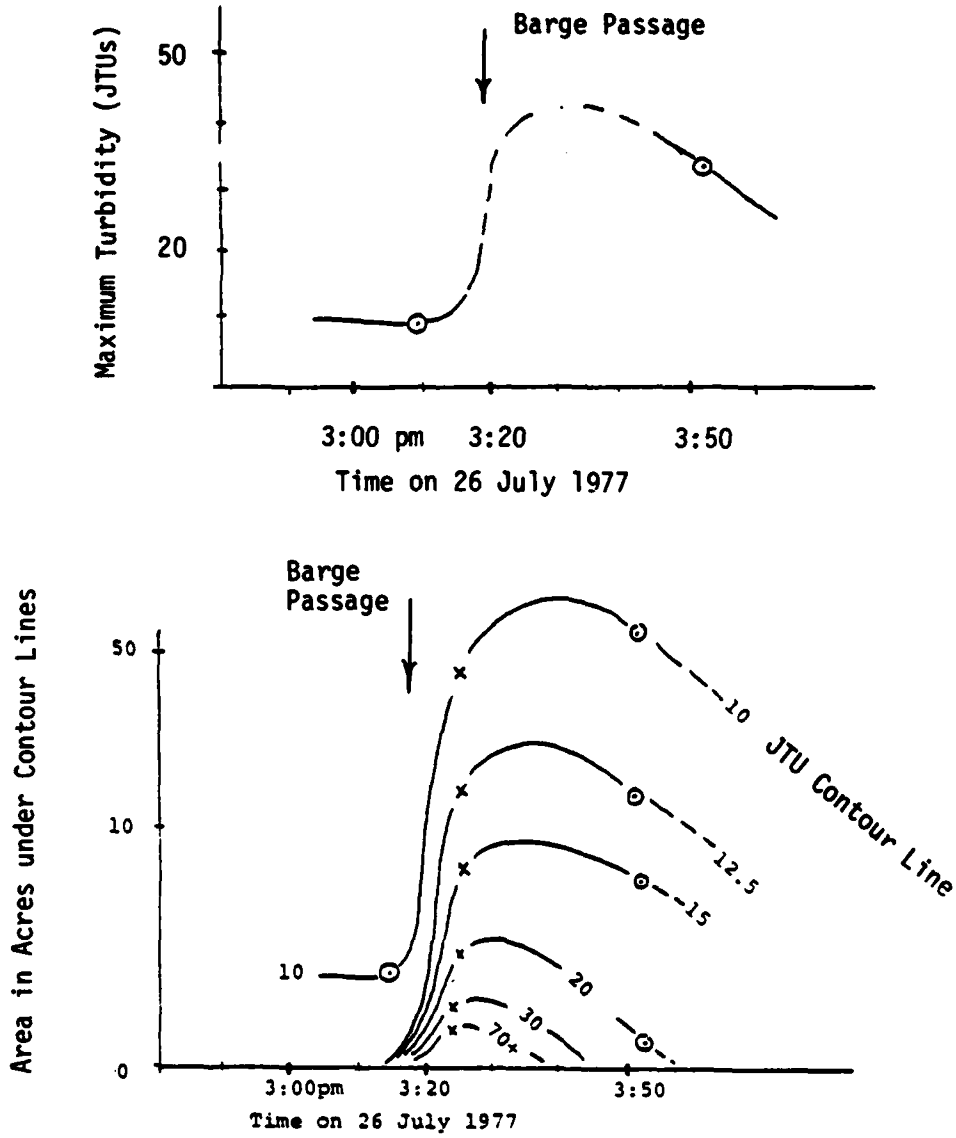


Figure 22. Effect of Barge Passage at 3:18 pm, 26 July on Turbidity near the Dredge Site

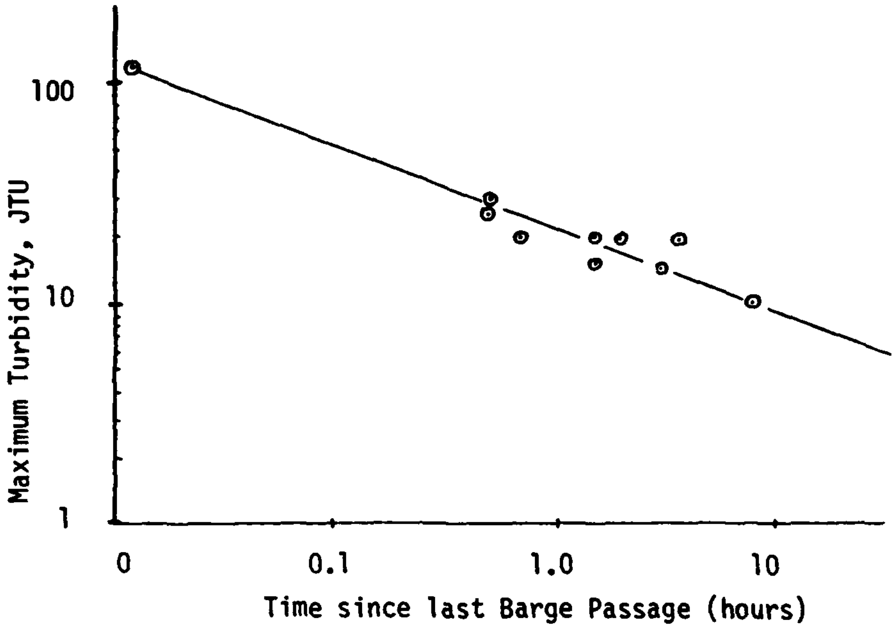


Figure 23. Surface Turbidities in River Versus Time since last Barge Passage

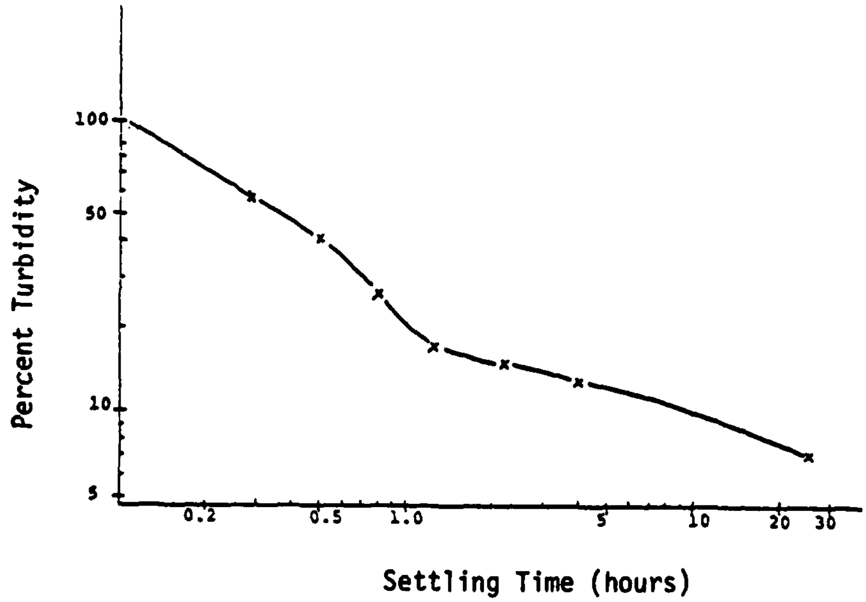


Figure 24. Settling Test Results Plotted on Log-Log Scale (Water Sample Collected in Barge Plume)

REFERENCES

Van Domelen, John F., "Photographic Remote Sensing - A Water Quality Management Tool," Ph.D. Thesis, University of Wisconsin, Madison, 1974.

Scherz, Adams, Scarpace, Woelkerling, "Assessment of Aquatic Environment by Remote Sensing," Institute for Environmental Studies Report 84, University of Wisconsin, September 1977.

Scherz, James P., "Analysis of Turbidity Plumes with Aerial Photos," Report for the U. S. Army Corps of Engineers at Saint Paul, Minnesota, December 1977.

HISTORICAL SKETCH - INTERDISCIPLINARY IMAGERY ANALYSIS FOR ENGINEERING, SCIENTIFIC AND MILITARY PURPOSES

ROBERT E. FROST

US Army Engineer Topographic Laboratories
Fort Belvoir, Virginia 22060

BASIC AND APPLIED RESEARCH

The present concept of interdisciplinary imagery analysis to obtain information about the physical, biological and cultural characteristics and engineering properties of the environment is an outgrowth of a continuity of research, application and training that spans the past 37 years. The present effort had its beginnings at Purdue University in 1942 in connection with the use of airphotos to map and describe drainage, soils/ rocks and engineering materials for use in location, design construction, materials survey and maintenance for the State Highway Commission of Indiana. The war effort resulted in expansion of the program through an airfield site selection project (1943-46) for the Civil Aeronautics Administration (36 air fields in the US which later became county airports). This early application identified a great need to do that research necessary to understand the imaging systems, their uses, limitations and how to extract information for engineering, scientific, and military purposes. Further, it became readily apparent the most information available was dependent upon detailed stereo analysis and exchange of view points by a small group representing several disciplines of science and engineering.

The Corps of Engineers, through the St Paul District, sponsored early research at Purdue in the Arctic/sub-Arctic in connection with soil/permafrost investigations and applications of the methods to military airfield site selection and construction (1945-50). This led to added university research in support of the Mobility and Trafficability Project of Waterways Experiment Station (1951-56). Engineer intelligence uses were developed through a university contract activity with Army Map Service (1954-56) resulting in production of the Photo Intelligence Manual Series. In 1953, USAF through Wright Air Development Center began to sponsor university research in the area of film/filter/scale studies in various mid US environments in order to better define uses and limitations of the photographic systems then being used by USAF. This continuity of basic and applied research, including key personnel, was transferred from the university in 1956 and has continued since that time at a succession of three Corps of Engineer Laboratories (USASIPRE - Snow, Ice and Permafrost Research Establishment 1956-60; USACRREL - Cold Regions Research and Engineering Laboratory - 1960-70; and USAETL - Engineer Topographic Laboratory 1970-date). The mission and function statements were broadened to include research in all environments and all aerial sensors via the interdisciplinary team concept (1956-date).

Basic research into matter-energy relationships was initiated in 1956 through a cooperative research effort between USASIPRE and the Infra Red Lab (Willow Run Lab, University of Michigan). Coordinated aerial sensing and ground sampling by an interdisciplinary team proved the feasibility of this concept. Early work with thermal IR sensing of ice and snow covered surfaces conducted at the SIPRE Keeweenaw Field Station (COLD DECK) was expanded and applied to the detection of crevasses in the Greenland Ice Cap. This cooperative research effort next concentrated on the problem of detecting guerrillas beneath the Puerto Rican tropical jungle canopy (TROPICAN), again via coordinated aerial thermal IR sensing and interdisciplinary ground sampling operations. This became the basis for using thermal IR sensors in Vietnam for guerrilla detection. Following this, the two laboratories cooperated in Operation HOT DECK -- a study of the thermal signatures resulting from such causes as sub-surface oxidation of ore bodies, hydrothermal activity, oxidation of lignite deposits and the heating and cooling characteristics of desert surfaces. This early research was expanded to include using various radars for sea ice sensing and reconnaissance, ice thickness and pressure ridge studies and terrain analysis (RATRAN). Other research and application included such subjects as cave location, radioactive contamination of vegetation, frost action in soils and vegetation pattern studies in the arctic, desert and tropical environments.

APPLICATION TO MILITARY AND CIVIL PROBLEMS

Since 1942, the methods and techniques of interdisciplinary image analysis have found successful application to support such major military projects as: site selection and analysis of 6 major airfields in Alaska (1948-49); project planning and development of Thule AFB (1951); DEW Line installations siting (1953-56); BMEWS site analysis at Thule Greenland (1955); US Navy Project SANGUINE in Wisconsin (1969); several missile site surveys (NIKE, SENTINEL, MINUTEMAN, 1968-72); intelligence manuals (1954-56) and effects of high explosives on vegetation (PRAIRIE FLAT) 1969. Studies in support of South East Asia included: mobility studies in Thailand (MERS, 1965); evaluation of seismic parameters (1967); camouflage considerations of the NBB (1967); environmental analysis in South Vietnam (1967); Ho Chi Minh Trail analysis (1968); deltaic features of the Mekong Delta (1968); terrain masking of radar (1969); and impact of herbacide defoliants in Vietnam (1974). Two studies in support of TRADOC interest in environmental analysis and impact assessment included: Environmental Analysis and Impact Assessment of Fort Bliss (1978-79 contract activity) and Fort Dix (1979 - joint interagency/interdisciplinary study "Man in the Pinelands").

Direct application to Civil Works projects has been in connection with a series of joint ETL/CW operational demonstrations as a means of illustrating the feasibility of utilizing interdisciplinary imagery analysis as part of the Civil Works project planning and development process. This included the following: Ohio River Division (1975) - reservoir and pump storage site analysis (Huntington), acid mine drainage and abatement (Pittsburgh), Big South Fork River and Recreation Project (Nashville) and Wabash River Canal Project (Louisville); Missouri River Division (1967) - Missouri River Bank Stabilization and Navigation Fish and Wildlife Study (Omaha and Kansas City); Southwestern Division (1976) - Clopton Crossing and Dam and Lake Project (Fort Worth); North Central Division (1976) - Des Moines River Bank Erosion Study (Rock Island); and North Atlantic Division (1976) - Baltimore Harbor and channels deepening study (Baltimore and Norfolk). Other studies in support of Civil Works included: Lake Michigan Diversion and Illinois River Impact (1978 - Chicago); Quad Cities Metro Study under Project River Bend 2020 (1978 - Rock Island); and Cochiti/Abiqiu Dams (1978 - Albuqerque). Latest applications of these methods have been to gather data useful in the defense of the Government in the area of bank erosion litigation (ORD - Ohio River bank erosion 1977 and Seattle District - Lake Pend Oreille bank erosion 1978-79).

SHORT COURSES IN INTERDISCIPLINARY IMAGERY ANALYSIS

The current intensive ETL "hands-on" short courses series was initiated while at CRREL by US Air Force Institute of Technology (Wright Patterson AFB) in 1967 for the purposes of developing and training small 5-man interdisciplinary airfield site selection teams. Since that time through continued sponsorship of USAF (1967-71) and Civil Works, OCE (1969-78) and others, a total of 44 courses have been conducted for 844 participants. In each course, the primary emphasis has been on interdisciplinary imagery analysis of the environment with pointed application to a wide range of projects (dams, disposal of dredge spoil, canals, recreation area selection and development, acid mine drainage and abatement, fish and wildlife mitigation, airfield site selection, and planning and development in Puerto Rico and Latin America). In many of the above short courses and demonstrations, the participants have come from all DOD agencies, several non-DOD federal agencies, state and local agencies and commissions, colleges and universities and foreign countries.

BENEFITS - INTERDISCIPLINARY IMAGERY ANALYSIS

There are many benefits to be derived from utilization of interdisciplinary imagery analysis methods in connection with project planning and development process for military and civil projects. General Heiberg, while serving as Division Engineer, Ohio River, in his summary statements at the close of the joint ETL/ORD demonstration/experiment listed five important benefits:

1. More complete consideration of alternatives at early stages of plan formulation.

2. Increased internal coordination.

3. More complete assessment of the existing conditions.

4. Quicker and less costly data collection.

5. More effective presentation of Corps decisions at public hearings.

Other benefits include the following:

6. Gain valuable lead time well in advance of design and construction activities or activities related to planned military operations.

7. Locate, plan, prioritize and conduct field verification and sampling activities based upon pre-determined area/site complexity and accessibility.

8. Locate, identify and describe areas of existing or potential geotechnical or seismic activity.

9. Trace natural and historical development in an area to determine and evaluate past and existing natural and man induced stresses conditions (often without access to field operations) for purposes of identifying existing base line environmental conditions. This will provide a basis for predicting performance and any likely stresses or impacts either adverse or beneficial.

10. Provide an intellectual professional enrichment for all participants and their respective agencies.

11. Develop and establish a long lasting and effective technical communication network between DOD and non-DOD agencies.

AD-A084 043   ARMY ENGINEER TOPOGRAPHIC LABS FORT BELVOIR VA   F/G 17/8
U. S. ARMY CORPS OF ENGINEERS REMOTE SENSING SYMPOSIUM, 29 - 31--ETC(U)
OCT 79

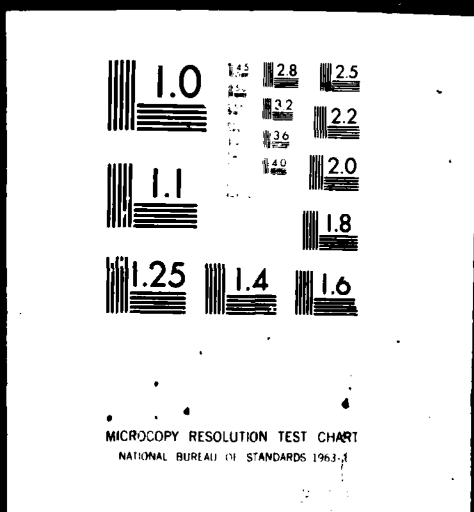
UNCLASSIFIED   NL

4 OF 4
AD
A084 043

END
DATE
FILMED
6-80
DTIC

4 OF 4

AD
A084 043



A STATISTICAL APPROACH TO RAINFALL ESTIMATION USING SATELLITE DATA

Linwood F. Whitney, Jr. and Leroy D. Herman

NOAA/NESS

Abstract

A statistical approach is employed in an attempt to estimate convective rainfall using satellite data. The objective is to provide rainfall estimates in a form suitable as input to hydrologic models which forecast riverflow. These models require area-averaged rainfall over periods of 6 hr in watersheds covering 500 sq mi or more.

Early in the study it was demonstrated that infrared temperatures alone are inadequate to estimate rainfall. A variety of additional variables derived from both satellite and conventional meteorological sources were then included in the study. All variables were thought to be physically or empirically related to the rainfall process. From among these variables, a screening regression method selected those which best explain area-averaged rainfall.

In both cases studied thus far, the selected variables correlated with rainfall at above 0.8. But since meteorological conditions in each case were very different, neither regression equation was a good estimator of the rainfall in the other case. Some of the most important variables selected were IR-temperature gradients along the tropospheric shear, ratio of IR-temperature to IR-temperature gradient along the low-level wind, low-level dewpoint, low-level dewpoint gradient along the high-level wind, and low-level dewpoint advection. Although these preliminary results are encouraging, many more cases must be included and any positive results checked against independent data.

(This paper is to be published in Satellite Hydrology a publication of the Proceedings of the Fifth Annual William T. Pecora Memorial Symposium at Sioux Falls, S. D., June 11-14, 1979.)

OPERATIONAL DATA COLLECTION AND PLATFORM LOCATION BY SATELLITE

M. TAILLADE

SERVICE ARGOS*
CENTRE NATIONAL D'ETUDES SPATIALES (CNES)
TOULOUSE, FRANCE

ABSTRACT

A new research tool offering unique features is now available following the launching of the Tiros-N and NOAA A satellites.

The Argos data collection and platform location system onboard these satellites is particularly suitable for gathering environmental data in three broad areas : the sciences of the atmosphere, the sciences of the seas and the Earth sciences. Compared with conventional data collection and transmission systems using cable and radio links, the Argos system is designed to be worldwide in its applications. The entire earth is scanned eight times a day and results are available at the Toulouse processing center in less than six hours.

* Address : Service Argos
Centre Spatial de Toulouse
18, avenue Edouard-Belin
31000 Toulouse - France

Telephone : (61) 52-1112 Telex : 531081 F

THE ARGOS SATELLITE-BASED DATA COLLECTION AND PLATFORM LOCATION SYSTEM

The ARGOS data collection and platform location system offers capabilities for the location of fixed and moving platforms and for the collection of data generated by platform sensors.

ARGOS is a cooperative project between the Centre National d'Etudes Spatiales (CNES, the French Space Agency), the U.S. National Aeronautics and Space Administration (NASA), and the U.S. National Oceanic and Atmospheric Administration (NOAA).

GENERAL DESCRIPTION

The Argos System comprises : (fig. I)

. a space segment consisting of two satellites in orbit at any one time, each being equipped with an onboard data collection system (or DCS) ensuring platform message reception, processing and retransmission,

. a set of user platforms, each being equipped with sensors and a platform transmitter terminal,

. the ground data processing centers.

1. SPACE SEGMENT

At any given time, the space segment of the Argos System will comprise two operational orbiting satellites.

Orbit characteristics : (fig. 2)

. Configuration : circular.

. Altitude (satellite I) : 830 ± 18 km
(satellite II) : 870 ± 18 km.

. Inclination : 98° (polar orbits ; during each orbit, each satellite "sees" both the North and South Poles).

. Period : 101 minutes (time required for each satellite to circle the Earth).

. Relative disposition : orbital plane of satellite I is inclined 60° relative to that of satellite II.

. Sun-synchronous orbits : the angle between the orbital plane of each satellite and the Sun direction is constant.

Each satellite crosses the equatorial plane at a fixed time (local solar time) each day.
These times are :
satellite I : 15 h (ascending node) and 3 h (descending node),
satellite II : 19 h 30 and 7 h 30.

This characteristic is important from the user's viewpoint since, from one day to the next, a given platform comes within a satellite's coverage at the same time (local solar time).

At any given moment, each satellite "sees" all the platforms located within a circle 5,000 km in diameter.

As the satellite orbits, the ground track of this circle corresponds to a swath 5,000 km in width encompassing the Earth. At each orbit, this swath covers both the North and South Poles (polar orbits). For a given satellite, the swath is displaced by 25° (i.e. 2,800 km at the Equator) every 24 hours as a result of the rotation of the Earth.

Data collection performance, which is determined by orbit geometry, is thus a function of latitude.

The following table gives approximate data for satellite visibility, as a function of latitude, for a 24-hour period.

latitude	cumulative visibility time over 24 hours	number of passes in 24 hours			mean pass duration
		min.	mean	max.	
± 0°	80 min.	6	7	8	
± 15°	88 min.	8	8	9	
± 30°	100 min.	8	9	12	
± 45	128 min.	10	11	12	10 min.
± 55°	170 min.	16	16	18	
± 65°	246 min.	21	22	23	
± 75°	322 min.	28	28	28	
± 90°	384 min.	28	28	28	

2. USER PLATFORMS

Each platform will be equipped with a platform transmitter terminal (PTT) providing the up-link between platform and satellite.

Platform sensors are linked directly to the PTT. Analog or digital data from up to 32 sensors can be handled by each PTT.

All PTTs transmit on the same frequency (401.650 MHz) and at regular intervals : every 40 to 60 seconds in the case of "location" platforms and every 100 to 200 seconds for "data-collection-only" type platforms. Each message transmitted includes that particular platform's number and the sensor output values sampled at the time of transmission.

Message duration is always less than 1 second.
The overall design of the Argos System is such that the PTTs providing up-links to the orbiting satellites offer the following features :

. simplicity : PTT electronics consists essentially of a transmitter

. lightweight : less than 1.5 kg

. low power consumption : approximately 200 mW on average

. ease of implementation

. low cost : 2000 to 3000 $ depending on type and options.

3. ONBOARD DATA COLLECTION SYSTEM

The onboard DCSs are equipped with receivers that pick up messages transmitted by platforms within the satellite's coverage. Message reception is on a random access basis. As each message is acquired, the DCS records the time and date, measures the carrier frequency and demodulates the platform identification number and sensor data.

Four messages can be received and processed at any one time.

These data are then formatted and stored by one of the onboard magnetic tape recorders. Each time the satellite passes over one of the three telemetry stations, the data recorded on tape are read out and transmitted to ground.

DIRECT TRANSMISSION

In addition to recording the DCS data, the spacecraft transmits it in real-time on 136.770 or 137.770 MHz. The DCS data is multiplexed with other instrument data at a low bit rate. Users can receive sensor data from platforms within the satellite's coverage at the time of transmission. However, platform position data cannot be obtained in this manner.

4. DATA COLLECTION

PTTs transmit their messages periodically, on the same frequency, independently of each other, and without the need for satellite interrogation.

The only communication links between user's platforms and the satellites are one-way platform-to-satellite links (or up-links). (fig. 3)

Messages from platforms within view of a satellite appear at the input to the onboard receiver in a random fashion :

. message separation in time is obtained through the asynchronization of transmissions and the use of different repetition periods,

. message separation in frequency is achieved as a result of the different Doppler shifts in the carrier frequency transmitted by the various platforms.

In the event of a number of messages reaching the receiver input simultaneously, up to four can be acquired provided they are separated in frequency.

The probability of acquisition of a message transmitted by a platform during a satellite pass in 0.99 provided all messages transmitted during periods of about 10 minutes are identical.

5. PLATFORM LOCATION

Principle of platform location

The location of each platform is determined solely by measuring the Doppler effect on the carrier frequency of in-coming messages (the transmitting frequency being fixed and the same for all platforms).

Each measurement made by the satellite corresponds to a field of possible positions of the platform under consideration. This field takes the form of a cone with the satellite at its apex and the velocity vector as the axis of symmetry.

The altitude of the satellite being assumed to be known, the intersection of several of these cones (each corresponding to a separate measurement) with the altitude sphere yields the solution.

Taking into account the nature of the geometrical fields concerned (cones with the orbits as their axes of symmetry), the statistical processing of the measurement data obtained by the satellite yields two symmetrical solutions relative to the ground track. One of these points is the required solution, the other its "image".

The ambiguity cannot be resolved without additional information, e.g. previous positions, range of possible speeds, etc.

The slower the platform moves, the more easily the ambiguity can be resolved.

Errors associated with platform location :

the main sources of error regarding platform location are :

. the accuracy with which the platform altitude is known. This is relatively unimportant in the case of drifting buoys, but may be very important in the case of balloons ;

. the stability of the PTT oscillator, in particular the drift in transmitting frequency during a satellite pass (approximately 10 minutes) ;

. the availability of information concerning platform speed and variations therein. The speed must be less than 100 m/s and is assumed to be constant between successive satellite passes.

Performance data for 99 % of cases	Drifting buoys	Drifting balloons
location accuracy	500 m	800 m
accuracy of speed determination	0,I m/s	0,3 m/s

6. CAPACITY OF THE ARGOS DCS

. for data collection only with a 99 % probability of data collection over 12 hours, the system capacity is : 16,000 platforms.

. for platform location (plus minimal data collection) with a 99 % probability of location over 24 hours, the system capacity is : 4,000 platforms.

These figures correspond respectively to 920 and 230 platforms falling simultaneously within the satellite coverage (i.e. platforms evenly distributed over the Earth's surface).

7. DATA PROCESSING CENTERS

Data are read out once every orbit, i.e. every 100 minutes for each satellite.

Once a satellite has completed telemetry data transmission for a particular pass, the received data are transmitted to the NESS (National Environmental Satellite Service) Center at Suitland (Maryland, USA). Data concerning the Argos System are separated from those concerning other satellite systems and transmitted to the CNES Toulouse Space Center where the Argos Data Processing Center is located.

The processing performed at the Center permits the determination of platform positions and the extraction of sencor data.

7.1 BREAKDOWN OF INTERVAL BETWEEN DATA COLLECTION AND AVAILABILITY

The minimum interval between data collection and data availability in a nominal system can be evaluated as follows :

. a particular message collected during a single orbit may have been stored up to 100 minutes before the onboard tape is played back to the ground telemetry station ;

. the time required for data transmission between the receiving telemetry station and the NESS facility is estimated at 45 minutes while the time required to retransmit Argos data to Service Argos is estimated at 20 minutes ;

. the time required to process the data generated by a single orbit is approximately 40 minutes ;

The interval between the time when a given platform message is acquired by the satellite and the time when the data is processed and available to users will vary between 1 hour 45 minutes and 3 hours 25 minutes depending on the platform's position.

These figures thus represent the ultimate possibilities of the system.

7.2 NORMAL INTERVAL

After the system has been declared operational, results are made availablc (at the Toulouse Space Center) to users not more than six hours after the onboard recording of the corresponding message. This period is termed the normal interval.

The difference between the ultimate possibilities of the system and the normal interval is the time required for equipment maintenance.

7.3 RESULTS SUPPLIED TO USERS

In the case of data-collection-only platforms the results supplied to users include :

. experiment identification code (project n° 1),

. platform number (Argos ID n°),

. time of data collection (expressed in universal time to within a few tens of milliseconds),

. sensor data after conversion to pure binary code or to physical units.

In the case of location-and-data-collection platforms, the results include all the above plus :

. time of location,

. position data (latitude and longitude),

. latitudinal and longitudinal velocity components in degrees per day.

8. DATA DISSEMINATION OPTIONS

Each user can choose between various modes of data dissemination to achieve an optimal time/cost trade-off for his particular requirements and circumstances.

8.1 OFF-LINE DATA DISTRIBUTION

Results, in this case, are made available to users from the data bank. Data stored in the bank are read out once a week for all users and held available for a period of three months only.

Results are available in the following forms :

. computer print-out,

. microfiches,

. magnetic tapes.

The normal mode of distribution is by post.

8.2 ON-LINE DATA DISTRIBUTION

Results, in this case, are supplied the moment they become available, i.e. immediately the corresponding data burst has been processed. A suitable high-speed means of communication must then be chosen from among the following :

. permanent links :

  — dedicated lines hired by the users,
  — the Global Telecommunications System (GTS) operated by the World Meteorological Organization (W.M.O.),

. links via switched networks (telex or telephone) :

  — sending of data following a telex or telephone call from the user (computer results files consulted directly).

9. APPLICATIONS OF THE ARGOS SYSTEM

The Argos System is particularly suitable for gathering environmental data in three broad areas : the sciences of the atmosphere, the sciences of the seas and the Earth sciences.

9.1 SCIENCES OF THE ATMOSPHERE

Firstly, meteorology. Thanks to Argos, it is possible to collect worldwide observations concerning the state of the atmosphere and hence to make longer range forecasts than was previously the case.

During 1979, Argos participates in the First Global GARP Experiment (FGGE) involving the deployment of a thousand drifting balloons and buoys. The four major objectives of the FGGE are :

. to obtain a better understanding of atmospheric motion for the development of more realistic models for extended-range forecasting, general circulation studies and climate ;

. to assess the ultimate limit of predictability of weather systems ;

. to develop more powerful methods for the assimilation of meteorological observations ;

. to design an optimum "composite" meteorological observing system for routine weather prediction of larger-scale features of the general circulation.

9.2 SCIENCES OF THE SEAS

Essentially, this means oceanography and, in particular, the study of such phenomena as :

- surface waves,
- water levels,
- water movement (currents),
- water temperature and salinity,
- ambient acoustic noise levels.

Parameters quantifying these phenomena will be measured at various depths.

9.3 EARTH SCIENCES

Potential applications of the Argos system in the Earth sciences can be summarized as follows :

Geology : monitoring and prediction of earthquakes and volcanic eruptions, prediction of fault movements, study of the thermal inertia of soil types.

Glaciology : study of the movements of icebergs and various studies in areas covered with ice and snow.

Hydrology : monitoring and prediction of natural water resources. Specific applications include :

- flood control,
- prediction of floods and droughts,
- monitoring of large river systems,
- hydraulic energy reserves,
- water reserves,
- irrigation.

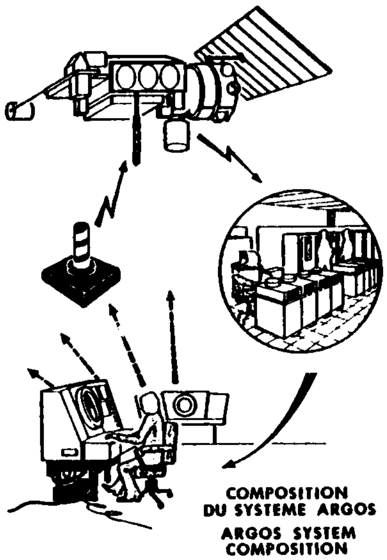


Fig. I

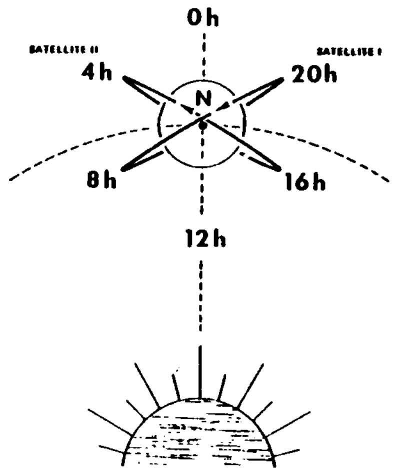


Fig. 2

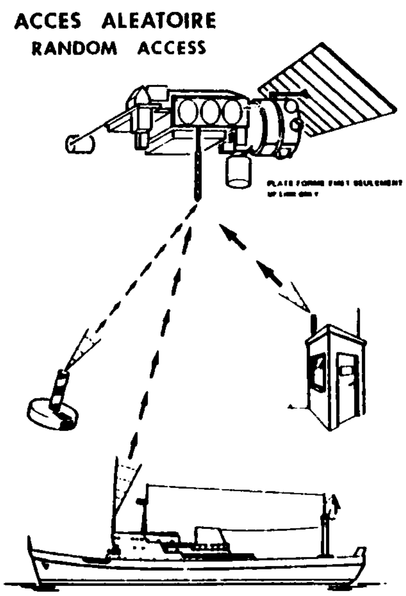


Fig. 3

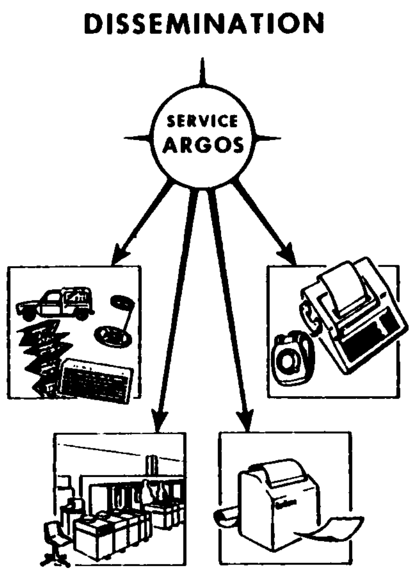


Fig. 4

USE OF REMOTE SENSING TO QUANTIFY CONSTRUCTION MATERIAL AND TO DEFINE GEOLOGIC LINEAMENTS DICKEY-LINCOLN SCHOOL LAKES PROJECT, MAINE

Harlan L. McKim
Carolyn J. Merry

U.S. Army Cold Regions Research and Engineering Laboratory
P.O. Box 282
Hanover, New Hampshire 03755 USA

and

Edwin A. Blackey

U.S. Army Engineer Division, New England
424 Trapelo Road
Waltham, Massachusetts 02154 USA

ABSTRACT

The Dickey-Lincoln School Lakes Project, a potential project for construction of a series of earth dams and dikes with a maximum height of 102 m is being evaluated by the New England Division, Corps of Engineers. The site is located on the St. John River in Aroostock County, Maine, approximately 48 km west of the town of Ft. Kent. The primary purpose of the project is to generate hydroelectric power, but it will also provide flood control and recreational areas.

During November 1974 a study was initiated to apply state-of-the-art remote sensing techniques to the delineation and quantification of surficial geology units to locate and define various types of construction material within the headwaters of the upper St. John River Basin. The primary objective of this study was to prepare a photogeologic base map and delineate surficial geology units within a 9.6-km and a 6.4-km radius of the major Dickey-Lincoln School dam site and dike areas, respectively. The secondary objective was to prepare a regional geologic lineament map from Landsat imagery.

Fourteen surficial geology units were delineated in a 2850-km^2 area in northern Maine from a photomosaic prepared from 1966 black and white photography (scale 1:33,600). These units included: alluvial fan, alluvial terrace, esker, floodplain, glacial moraine, kame, kame terrace, outwash, outwash terrace, bedrock, till, till over bedrock, wet outwash and wet till. The surficial geology units were field checked and then updated from the field reconnaissance. The depths of the surficial geology units were estimated utilizing borehole data, field measurements and seismometer data.

The areal extent of each surficial geology unit within a 6.4-km radius for the three dike sites and a 9.6-km radius for the main dam site was quantified using a planimetric color densitometer. The volumes of construction material were computed based upon these areal determinations and estimated depths. Considerable time was saved using remote sensing techniques to obtain this information instead of conventional ground surveys.

The volume estimates obtained were compared with the estimates of required construction material computed during the initial design phase. The comparison showed that more material could be found within the prescribed area around the dam and dike sites than was required for construction. The reduction in transportation distances determined from this study could result in considerable savings in cost as transportation of materials is a major cost in dam construction.

The lineaments observed on the Landsat imagery (scale 1:500,000) provided a sound base for analysis of possible tectonism in the Dickey-Lincoln area. It is believed that the east- and northeast-trending lineaments in this area are thrust faults dipping 45° to the northeast. The north-trending and N60°W lineaments are probably strike-slip normal and reverse faults dipping 80° to nearly vertical. Future movement along these faults should be negligible.

During the summer and fall of 1977 additional boreholde data were obtained in the Dickey-Lincoln area. These new data provided for further verification and refinement of the estimated depths and composition of four surficial geology units. These units included the alluvial terrace, kame terrace, outwash and outwash terrace. In all cases greater depths were found for each surficial geology unit.

WETLAND MAPPING USING LANDSAT [1]

Donald C. Rundquist [2]
Michael C. Gilbert [3]

ABSTRACT

Although Landsat data have been applied to a wide variety of earth-resource problems in an experimental fashion, it appears that relatively few projects have been undertaken which involve large geographical areas and a production mode of operation. One example of the implementation of Landsat digital procedures to a large-scale project was the result of a contract between the Remote Sensing Applications Laboratory (RSAL), University of Nebraska at Omaha and the Regulatory Functions Branch, Omaha District, U.S. Army Corps of Engineers. The intent of the contract, let in December of 1978, was to provide baseline information on the location and areal extents of wetlands within the 420,000 square-mile area comprising the Omaha District.

INTRODUCTION

Identification and classification of the wetlands in the Omaha District was based on data collected by the Multispectral Scanner (MSS) aboard the Landsat vehicles. The MSS is a line scanner incorporating an oscillating mirror that continuously scans a series of swaths perpendicular to the orbital path. Reflected solar energy is recorded simultaneously by the detectors built into the MSS receiver in four "bands" of the electromagnetic spectrum; Band 4 (visible green, .5 to .6 micrometers), Band 5 (visible red, .6 to .7), Band 6 (near infrared, .7 to .8) and Band 7 (near infrared, .8 to 1.1).

The data format used for the wetlands inventory consists of Landsat scenes that are 185 by 185 km in area (115 by 115 statute miles). Each of the MSS scan lines required to cover the 185 km north-south lenth traverses the 185 km width of the scene. As this occurs, the MSS records 3,240 individual readings along the scan line. The result is reflectance data (scale 0-127 in Bands 4, 5, and 6 and 0-63 in Band 7) for an enormous number of individually sensed cells (termed "pixels"), each of which is approximately .45 ha (1.12 acres) in size.

[1] Paper presented at the U.S. Army Corps of Engineers Remote Sensing Symposium, Reston, Virginia, October 29-31, 1979.
[2] Director, Remote Sensing Applications Laboratory, University of Nebraska at Omaha, Omaha, Nebraska. Others at RSAL, including L.C. Hamilton, J.S. Linden, and J.K. Turner, contributed to the development of the project.
[3] Ecologist, Omaha District, Corps of Engineers, Regulatory Functions Branch, Omaha, Nebraska.

The radiance information telemetered from the satellite is stored in digital form on a Landsat Computer-Compatible Tape (CCT), one of each 185-by-185 km area traversed by the space vehicle. The digital data are used to "create" imagery (e.g., 1:1,000,000 scale) of the earth's surface. The maximum potential of the Landsat system, though, is realized only when the original digital information (scale ca. 1:24,000) is utilized.

PROCEDURES

Development of "Eco-Regions"

The size and diversity of the Omaha District dictated a careful examination of the natural variables (such as physiography, vegetative cover, and soils) that could affect wetland "signatures" on Landsat imagery. Thus, prior to any wetland classification, the study area was subdivided into distinct "eco-regions," geographical entities that are relatively homogeneous in terms of the variables noted above. These eco-regions were further subdivided into "eco-cells," small units possessing somewhat distinct overall tonal characteristics on the Landsat (visual) imagery. Once this information was synthesized and properly integrated, mapping polygons were developed.

Establishment of Classification "Targets"

Within the respective mapping polygons, "target" sites were established, each one corresponding to the area of a USGS 7½-minute map. These areas, which were studied intensively, served as the "training sites" for the development of the spectral signatures to be used in the automatic classification of the wetlands in the corresponding mapping polygons.

Computer Classification

The analysis of the Landsat digital data began with simple "level-thresholding." That is, an initial "dump" of the CCT data for each Landsat band was evaluated carefully. The radiance values in each of the four channels for every pixel in the target quads were examined; i.e., the spectral response from the terrain was studied with regard to the landcover categories found within the boundaries of the study sites. In other words, the numerical range of the radiance values for pixels known to be geographically located within a wetland area was analyzed. The ranges (or the "thresholds") for each landcover class were eventually established by repeated comparisons of the spatial arrangement of pixel "clusters" (pixels with similar radiance values) on the computer rendition with ground-truth information. When a general agreement between the terrain features as represented by the computer for a particular Landsat band and the ground-truth was achieved, the thresholds for that band were considered defined.

For purposes of maximizing the cost-effectiveness of the project and in view of the immense size of the Omaha District, it was determined by RSAL that a simple dual-channel (MSS-5 and -7) classification scheme was best. The clustering algorithm is based upon the establishment of radiance thresholds for each of the wetland categories using Bands 5 and 7 for the individual mapping polygons. Thus, each eco-cell contained a unique set of wetland signatures.

Ground Verification

Many sources of information served as forms of "ground-truth" in the development of the classificatory procedures. Reference was made to Landsat-3 Return Beam Vidicon (RBV) imagery, NASA high-altitude aerial photography, and medium-altitude imagery obtained from various state agencies. But the primary tool used in guiding the wetland classification with Landsat MSS data was 35-mm color-infrared film flown at low altitudes. Numerous flightlines throughout the Northern Plains were flown, and resulted in approximately 4,500 slides. This imagery, allowing superior spatial resolution and clarity, has proven to be an invaluable reference for the inventory.

Wetland Categories

The wetland classification for the inventory of the Omaha District was based on the following:

Corps Wetland Definition--

"Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."

General Definitions of Wetland Classes--

Open Water - Areas of open surficial water large enough to be detected by the Landsat MSS.

Subirrigated Meadow - Areas not irrigated by man that occupy topographic lows where plant roots contact the water table. These low-lying areas are typically occupied by vigorously growing grasses, sedges, and shrubs that contrast sharply with the adjacent upland vegetation. For purposes of the present project, the meadows occur only in the Sandhills Region of Nebraska, where they are interdunal in nature.

Marsh - Areas of emergent aquatic vegetation, often associated with areas of open water.

Riparian - Areas of riverine vegetation where the growth of the plant communities is a result of the presence of a flowing stream. For Landsat pixels to be classified into this category, they must be associated with a flowing stream)otherwise, they would be classified as "marsh").

This classification system was adopted prior to the actual start of the project, and was purposely left rather general and somewhat flexible. From a management standpoint, it was decided that the primary interest of the District was the fundamental question: "Is it a potential wetland; yes or no?"

RESULTS

Map Production

The classification scheme tailored for each mapping polygon was implemented across the Omaha District with output in the form of computer plots at a scale of 1:24,000. The plots were then superimposed onto the corresponding USGS 7½-minute quadrangles and physically adjusted for the geometric inequalities in the CCT data. The final wetland maps were produced in the form of mylar overlays. When the project is completed, the Omaha District will possess an estimated 8,000 maps illustrating the wetlands of their area of jurisdiction.

Information System for Wetlands

Once the final map is drawn and edited, the acreage totals for the wetland groups on each map, as measured by RSAL's digital planimeter, were annotated to the finished map. These acreage totals were then input to the data bank constructed specially for the inventory of the Omaha District. This information system is currently being evaluated for its use in both in-house analyses and for the public dissemination of the inventory data. The potential for computer mapping at various scales -- quad, county, state, or district -- would seem especially promising.

NATIONAL WETLANDS INVENTORY PROJECT
INVENTORYING THE NATION'S WETLANDS WITH REMOTE SENSING

RUDOLF NYC
Corps of Engineers Representative
PAUL BROOKS
U.S. Geological Survey Representative

National Wetlands Inventory
U.S. Fish & Wildlife Service
Dade Building, suite 217
9620 Executive Center Drive N
St. Petersburg, Florida 33702

ABSTRACT

In 1974 the U.S. Fish and Wildlife Service directed its Office of Biological Services to design and conduct an inventory of the Nation's wetlands. The mandate was to develop and disseminate a technically sound, comprehensive data base, concerning the characteristics and extent of the Nation's wetlands. The purpose of this data base is to foster wise use of the Nation's wetlands and to expedite decisions that may affect this important resource. To accomplish this, state-of-the-art principals and methodologies pertaining to all aspects of wetland inventory were assimilated and developed by the newly formed team. The following is a summary of how this team, formally known as the National Wetlands Inventory, is organized, how it operates and how it is accomplishing its goal.

---

1. NWI ORGANIZATION STRUCTURE

The central National Wetlands Inventory (NWI) operational team is the focal point for coordinating all activities concerning the inventory. Located in St. Petersburg, Florida, the staff consists of Fish and Wildlife Service (FWS) personnel and a representative from the U.S. Army Corps of Engineers, the Soil Conservation Service, and the U.S. Geological Survey (USGS). Other agencies not represented at the central office have established formal points of contact who are responsible for coordination with the NWI. A service support contractor is also located in close proximity to the central office. In addition to the central office staff, there are seven Regional Wetland Coordinators, one in each of the six FWS Regional Offices, plus Alaska, and two full-time personnel in Washington, DC, involved principally in budgetary and planning efforts.

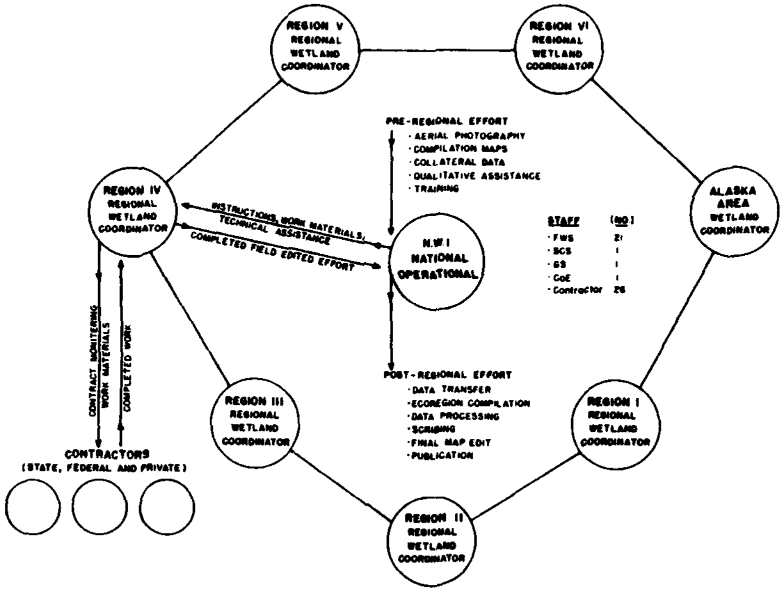


Figure 1. Network Diagram of the National Wetlands Inventory Operational Work Flow.

2. WETLANDS CLASSIFICATION SYSTEM

The first National wetlands inventory completed in 1954, utilized a classification system that compartmentalized wetlands into 20 broad types (Circular 39, Martin et al., 1953). This was satisfactory at that time, since the purpose of that inventory was principally to assess waterfowl habitat. The Martin et al. system, however, could not be used to effectively achieve the broader goals of the new NWI.

The new classification system (Cowardin et al., 1977) consists of five broad ecological systems (Marine, Estuarine, Riverine, Lacustrine, and Palustrine), each of which contains a hierarchial structure that describes, in progressively greater detail, hydrological, biological, and geological components of a wetland or water body. The following example of the estuarine system illustrates the hierarchial structure:

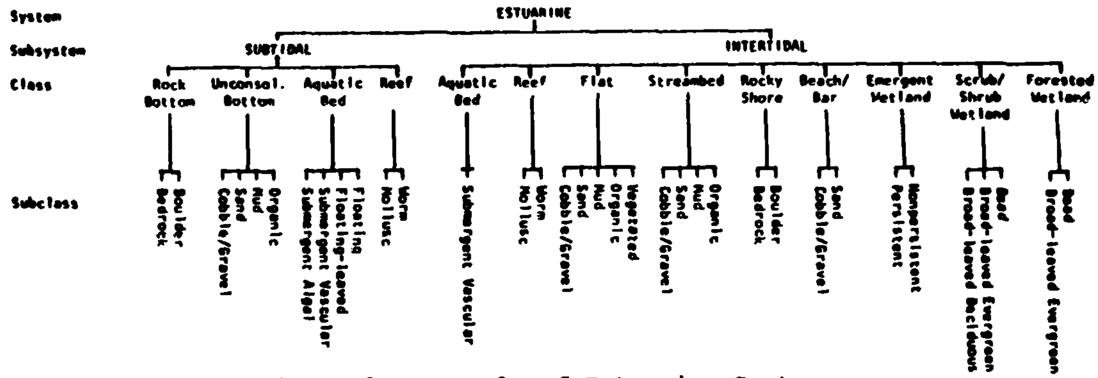


Figure 2. Example of Estuarine System.

To achieve a greater degree of descriptive detail, modifiers are added to the lower levels of the classification hierarchy. These modifiers include water regime, water chemistry and a special category that describes events that have impacted on the wetlands such as "diked/impounded".

Each element of the classification system is identified by either a letter or a number. The composite code identifying a particular wetland consists of a series of letters and numbers and is referred to as an alpha-numeric. The following is a typical alpha-numeric illustrating how a wetland is classified to the water regime, with special modifier level of detail:

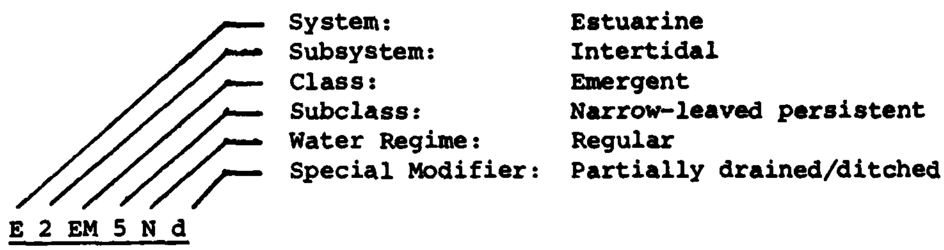


Figure 3. Classification of Wetlands to Water Regime and Special Modifier.

In the Northwest, this particular code would be indicative of a wetland plant community dominated by sedges (Carex lyngbyei). Wetland classes and subclasses can be mixed as is shown in the following example:

E2FO3/EM5N = Estuarine intertidal, forested, broad-leaved evergreen (E2FO3), mixed with Estuarine interdial, emergent, narrow-leaved persistent (E2EM5) with a regular water regime (N).

Figure 4. Example of Mixing Classes and Subclasses.

In Florida, this would indicate a wetland plant community consisting principally of mangroves (Rhizophora mangle) and salt marsh cordgrass (Spartina alterniflora).

3. SELECTING THE REMOTE SENSING SYSTEM

Remote sensing was the obvious answer to the problem of inventorying the Nation's wetlands in a relatively short period of time. What was not so obvious was which tool to use in the ever increasing technological arsenal of remote sensing systems. Because of the immensity of the task, the number of choices was quickly narrowed to LANDSAT and high altitude aerial photography. After comparing LANDSAT's capabilities with the expressed needs of FWS regions and local agencies for wetland inventory information, it became evident that LANDSAT could not provide the desired level of detail without what appeared to be an excessive amount of collateral data such as aerial photographs and field work. When it also became apparent that the new wetland classification system that was being developed for the NWI could not be used to conduct an inventory with LANDSAT, the decision was made to use high altitude aerial photographs. Realizing that the state-of-the-art would continue to evolve, the NWI has been participating in cooperative demonstration studies for mapping wetlands with LANDSAT. The most promising application of LANDSAT data appears to be for change detection and updating of wetland maps.

4. ACQUISITION OF HIGH ALTITUDE AERIAL PHOTOGRAPHS

The scales of the aerial photographs used by the NWI range from 1:60,000 to 1:130,000 with 1:80,000 quad-centered color infrared being the preferred scale and type of imagery for conducting the wetland inventory. (Appendix A illustrates the number of aerial photographs required at various scales to cover one 1:100,000 scale map block. When taking into consideration the combined cost of air photo acquisition, plotting work areas on the photos, photointerpretation and transferring the annotated information to overlays/maps, the cost for inventorying the Nation with large-scale photography would be prohibitive.)

Priorities for wetland mapping are based principally on needs of FWS regions and those of other Federal and state agencies. As soon as an area has been designated as a priority and the necessary funding has been allocated, a complete search for suitable high quality aerial photographs is conducted. Usually, available aerial photographs are obtained through the EROS Data Center, though other sources are used on occasion. At the same time as the aerial photographs are ordered, additional pertinent information, including soil surveys, regional wetlands inventories, topographic maps, nautical charts and reports, are assimilated at the central office.

When suitable imagery is not available in priority areas, contracts for aerial photographic acquisitions are prepared by the central office. This is generally accomplished in conjunction with other agencies, such as the U.S. Geological Survey and the Corps of Engineers. Beginning in FY 80, the NWI will obtain most of the imagery it needs from the newly formed Federal High Altitude Aerial Photography Data Base Program. To meet the different needs of this interagency group, 1:80,000 black and white and 1:60,000 CIR aerial photographs will be imaged simultaneously. All of the conterminous United States will be imaged by this program on a 3-5 year cycle. USGS is the lead agency in this program and additional information may be obtained by writing to:

Mr. Paul A. Antill
U.S. Geological Survey
512 National Center
12201 Sunrise Valley Drive
Reston, Virginia 22092

5. AERIAL PHOTOINTERPRETATION

Upon receipt of the aerial photographs at the central office, the imagery is sorted and filed by USGS 1:100,000-scale quadrangle map areas. Work areas are drawn on the photos to aid the photointerpreter and to ensure that all adjacent photographs overlap so that wetlands on the edge of work areas "tie" together. The aerial photographs and all collateral data are forwarded to the Regional Wetland Coordinator.

The aerial photointerpretation is performed by contractors which are generally either State or private organizations. The Regional Wetland Coordinators have the principal responsibility for the successful completion of the photointerpretation phase of the wetland inventory.

After the aerial photointerpreter (API) has been trained in the use of the new wetland classification system and is familiar with all available collateral data, he proceeds with a preliminary classification of wetlands. Generally, this consists of about 10% of the work area, with emphasis placed on identifying potential problem areas. After a sufficiently large number of photographs have been interpreted in this manner, the API is accompanied in the field by the Regional Wetland Coordinator to resolve any problems. Usually, the most difficult part is delineating the upland from wetland boundary and identifying the correct water regime. As the photointerpretations are completed for each 1:100,000 scale quadrangle, the API again proceeds to go to the field to verify the photointerpretations. If the Regional Wetland Coordinator is satisfied with the work, he forwards the annotated photographs with all collateral data to the central office for quality control review. In addition to accuracy of wetland boundary delineations and classification, adherence to mapping conventions is also reviewed during this quality control step to ensure National consistency. If the photointerpretation passes this quality control review, it is forwarded to the cartographic laboratory for production of large scale overlays and small scale maps.

6. CARTOGRAPHIC PRODUCTION

The service support contractor, under the guidance of the NWI staff, is responsible for the cartography involved in preparing large scale overlays and small scale maps.

6.1 LARGE SCALE WETLAND OVERLAYS

The wetland interpretation data on the aerial photographs are transferred to an overlay on a large scale USGS base map using a zoom transfer scope. During this process, most distortions in the aerial photography, and therefore wetland delineations, are eliminated. Quality control review following the zoom transfer process also may reveal errors due to photointerpretation. Draft overlays are then reviewed in the field by the Regional Wetland Coordinator for accuracy of photointerpretation and zoom transfer. Draft wetland overlays are also reviewed by other Federal agencies, including the Corps of Engineers and the Soil Conservation Service. After all corrections have been made, the final overlays are produced.

6.2 SMALL SCALE MAPS

The final large scale overlays are used to prepare the NWI 1:100,000 scale topical wetland map series. Each overlay is photographically reduced on a copy camera, composited, and paneled to a USGS base map. (There are 32 7.5-minute quads and 8 15-minute quads that comprise one 1:100,000 scale map quadrangle.) Where 1:100,000-scale USGS base maps have not yet been prepared, the NWI produces only a composite overlay.

6.3 MAPS AND OVERLAYS COMPLETED TO DATE

To date, the NWI has completed over 2,000 draft or final large scale overlays encompassing an area of 125,000 square miles. Also, 33 1:100,000 scale maps or composite overlays, have been completed.

7. DISSEMINATION OF CARTOGRAPHIC PRODUCTS

The NWI has a limited reproduction and dissemination capability that was implemented in order to make maps and overlays available to potential users. To date, 25,000 copies of draft and final overlays have been distributed under this interim dissemination program. The long-term dissemination strategy is to utilize, through a cooperative agreement, the U.S. Geological Survey's reproduction and distribution facilities for dissemination of NWI products. For information concerning the availability of NWI products, contact the appropriate Regional Wetland Coordinator shown in Appendix B.

8. WETLAND INFORMATION AND REPORTS

In addition to cartographic products, the NWI is developing technical data and providing reports in order to fully comply with the mandate with which it has been charged.

8.1 WETLAND AREA MEASUREMENT DATA

The large scale overlays are also used to obtain area measurement data that, after computer processing, provides statistical information concerning the number of acres of a specific wetland classification type that is located in a particular state, county, Bailey Ecoregion, Hammond's Land Form, USGS hydrologic unit and USGS large and small scale maps. This data may be manipulated by computer to obtain any desired variation of the basic input information.

8.2 LIST OF HYDRIC SOILS

The Soil Conservation Service representative assigned to the NWI is preparing a list of hydric soils for the entire Nation, including Alaska and Hawaii. A preliminary list for selected portions of the country will be available by 1 January 1980. In addition to helping identify wetlands in the field, this list will make existing products, such as SCS's soil survey maps, more useful as a data base for wetland evaluation.

8.3 LIST OF HYDROPHYTES

The list of wetland plants is being developed by FWS to more specifically define "hydrophyte" as it is used in the definition of "wetland" contained in the new wetland classification system. The list of hydrophyte species will actually be a species data base containing species taxonomy (including synonymies, habitat, with reference to authors and manuals), wetland specificity or indicator status of the species, distribution by state, wetland communities and/or forest type the species is reported to be a component of, and flowering time of the species. Information from the 1971 SCS National List of Scientific Names, along with revisions to this list currently underway by the Smithsonian Institute, will be incorporated directly into the hydrophyte species data base.

A more comprehensive wetland (hydrophyte) community data base, which incorporates and expands on the information from the hydrophyte species data base is being developed concurrently.

A preliminary list of hydrophytic species will be submitted for review during 1980. The hydrophytic community data base should be available in draft form during 1981.

8.4 REGIONAL, STATE AND NATIONAL REPORTS

For each 1:100,000 scale quadrangle inventoried, the NWI is preparing "Notes to Users" which provide information about the imagery used and documents the Regional Wetland Coordinators' observations concerning wetlands in that area.

The "Notes to Users," along with pertinent collateral data will be consolidated with "State Reports" to document the status of wetlands at the time of the inventory.

Ultimately, the State Reports will be consolidated and summarized to prepare an authoritative report on the status of the Nation's wetlands.

8.5 TREND ANALYSIS

In order to document the changes that have occurred to the Nation's wetlands over the past 20 years, the NWI is conducting a wetland trend analysis that will utilize 1950 and 1970 era aerial photographs, the new wetland classification system, and sophisticated statistical procedures.

9. NWI DATA BASE MANAGEMENT SYSTEM

The NWI has developed a Wetland Analytical Mapping System (WAMS), which, when fully operational, will make it possible to digitize wetland information directly from unrectified aerial photographs by stereoscopic compilation to produce wetland maps that are more accurate than those from the current cartographic procedures. Since the storage system in WAMS is geo-based, it is possible to rapidly up-date site-specific information and retrieve data either as a computer printout or as a map at any desired scale. WAMS is currently undergoing preoperational testing at Fort Collins, Colorado.

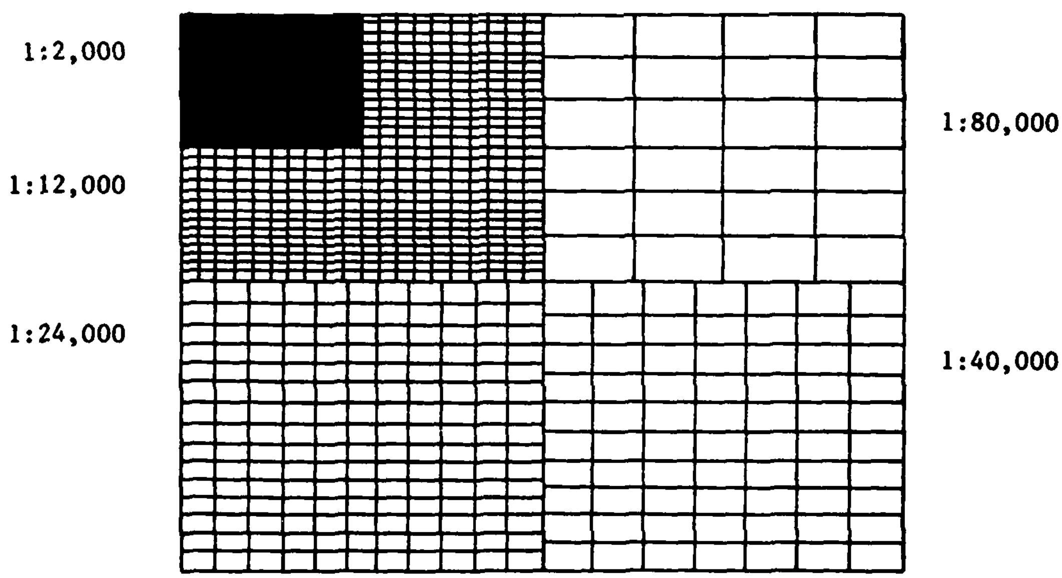
10. CONCLUSION

With high quality imagery of the desired scale and type virtually assured by the new Federal High Altitude Aerial Photography Data Base Group, and the promising results from the preoperational testing of WAMS, only the increased support and cooperation the NWI is receiving from other Federal agencies provides more assurance that the goals of the National Wetlands Inventory will be achieved in an expedient and cost-effective manner.

APPENDIX A

COMPARISON of the number of aerial photographs required for complete stereoscopic coverage of a USGS 1:100,000 scale area (1,667 sq miles) using 60% forward overlap and 30% sidelap with various scales of photography:

Scale of Photography	Area Covered by One (1) 9"x9" Photo	Number of Photos
1:2,000	0.1 sq mi	74,601
1:12,000	2.9 sq mi	2,255
1:24,000	11.6 sq mi	630
1:40,000	32.5 sq mi	260
1:80,000	127.7 sq mi	84
1:120,000	290.7 sq mi	50



USGS 1:100,000 Scale Area

Visual conception of 9"x9" photo coverage with 60% forward and 30% side overlap at various scales.

APPENDIX B

Region	Geographical Area	Regional Wetland Coordinator
1	*Alaska, California, Nevada, Hawaii, Oregon, Washington	Dennis Peters, US Fish & Wildlife Service, Lloyd 500 Building; suite 1692, 500 NE Multnomah Street, Portland, OR 97232 COM: 503/231-6116 FTS 429-6154
2	Arizona, New Mexico, Texas, Oklahoma	Warren Hagenbuck, US Fish & Wildlife Service, PO Box 1306, Albuquerque, NM 87103 COM: 505/766-2914 FTS: 474-2914
3	Minnesota, Wisconsin, Illinois, Indiana Michigan, Ohio	Ron Erickson, US Fish & Wildlife Service, Federal Building, Ft. Snelling (AS/BSP), Twin Cities, MN 55111 COM: 612/725-3593 FTS: 725-3593
4	Arkansas, Louisiana, Florida, Mississippi Alabama, Georgia, South Carolina, North Carolina, Tennessee, Kentucky, Puerto Rico	John Hefner, US Fish & Wildlife Service, R.B. Russell Federal Building; 75 Spring Street SW, Atlanta, GA 30303 COM: 404/221-6343 FTS 242-6343
5	Maine, Vermont, New Hampshire, New York Massachusetts, Connecticut, Rhode Island, Pennsylvania, New Jersey, Delaware, Maryland, West Virginia, Virginia	Ralph Tiner, US Fish & Wildlife Service, One Gateway Center, suite 700, Newton Corner, MA 02158 COM: 617/965-5100 FTS: 829-9217
6	Montana, Wyoming, North Dakota, South Dakota, Nebraska, Utah, Colorado, Kansas Iowa, Missouri	Charles Elliott, US Fish & Wildife Service, PO Box 2548, Denver Federal Center, Denver, CO 80225 COM: 303/234-5586 FTS: 234-5586
* 1	Alaska	Art Laperriere, US Fish & Wildlife Service, Alaska Area Office, 1011 East Tudor Road, Anchorage, AK 99503 COM: 907/2976-3800 x412 FTS: 399-0150

AQUATIC PLANT MAPPING BY REMOTE SENSING

L. E. Link, Ph.D., and K. S. Long
U. S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

ABSTRACT

This paper presents a synopsis of the results of simulation modeling and field studies from which methodologies were formulated for application of remote sensing to the aquatic plant mapping problem. A large-scale demonstration project is discussed to illustrate the operational effectiveness of the methods.

1. INTRODUCTION

In 1975 responsibility for the research efforts in the control of aquatic plants was assigned to the U. S. Army Engineer Waterways Experiment Station (WES) with priority to be given to rapid transfer of available technology to the operational elements of the Corps. A portion of this effort is devoted to developing the capability to identify and assess rapidly the nature and extent of aquatic plant infestations. Because accurate ground surveys of these infestations are very often impractical and expensive, remote sensing technology was applied to the problem.

The overall objective of the WES remote sensing work was to develop two capabilities, both of which could be applied within the existing Corps of Engineers District resources: (1) a reconnaissance technique, or a means to look at very large areas to rapidly identify potential aquatic plant problems, and (2) a detailed survey capability that would be used to assess the type and extent of aquatic plant infestations at a level that would be meaningful for application or evaluation of control measures.

A series of experiments that involved both simulation modeling and field tests were set up to evaluate candidate remote sensing systems. The methodologies resulting from these efforts were then evaluated for their operational effectiveness by conducting a large-scale demonstration project. The following paragraphs present a synopsis of the results of those studies and a more detailed discussion of the result of the large-scale demonstration project.

2. SYNOPSIS OF SENSOR SYSTEMS EVALUATIONS

2.1. Reconnaissance Survey Capability

Remote sensor systems evaluated for reconnaissance mapping of aquatic plants were Landsat, high-altitude aerial photography, and synthetic aperture side-looking radar. The evaluations were made by field tests at selected locations in Florida, Louisiana, Mississippi, and South Carolina.

Results of the field tests showed that Landsat imagery could be used effectively to depict areas with emergent or floating aquatic plant infestations, if the infestations are large enough to be resolved by the sensor system. Plant infestations that are submersed could not be detected reliably with the current Landsat imagery. The easy availability of Landsat images, periodic coverage, and relatively low cost for pictoral products are definite advantages. The inability to consistently detect submersed plant infestations, the inability to spatially resolve small water bodies (less than a few pixels in dimension) sufficiently for visual interpretation, the relatively high cost of digital analyses for larger areas (i.e. many scenes), and the time required to acquire Landsat imagery after it is received from the satellite are disadvantages. Landsat imagery provides a limited capability for discriminating plant species if the interpreter has prior knowledge of species in the study area.

High-altitude false-color infrared aerial photography (photo scales from 1:60,000 to 1:120,000) can be used at the original scale for reconnaissance purposes; the same images can be enlarged five times or more to examine smaller areas in more detail. The major disadvantage of the use of high-altitude aerial photos for very large areas is the relatively high cost (compared to Landsat) of acquiring the imagery and the relatively large number of photos that need to be handled. Both surface and submersed plant infestations can be effectively delineated on properly acquired false-color infrared photos, the spatial resolution is considerably better than that of Landsat images.

Radar imagery can detect floating or emergent plant infestations and allows all-weather imaging, day or night, but it would be expensive to acquire and does not have the capability to detect submersed plant infestations.

2.2. Detailed Survey Capability

Aerial photography was considered the only widely available and practical means for conducting detailed aquatic plant surveys over individual water bodies. Both simulation modeling experiments and field studies were conducted to determine the best aerial photographic systems for use in aquatic plant mapping. The model studies were used to screen the multitude of film-filter combinations available and to pick those that have the most potential for detecting aquatic plant infestations from their respective backgrounds, and for discriminating among the aquatic plant species of interest. The spectral reflectance characteristics of over 20 species of aquatic macrophytes and their surroundings, measured in various locations around the United States at various times of the year, were put into the model. Film-filter combinations with the most potential for discrimination were selected. Field studies were conducted at selected sites to further evaluate these prime film-filter combinations.

Conclusions reached on the basis of these studies are as follows:

(1) False-color infrared photography taken with a yellow (No. 12) filter and overexposed by one F-stop provides the most generally applicable tool for mapping aquatic plant infestations, both surface and submersed.

(2) The information derived from the imagery is very much a function of the knowledge of the interpreter. The optimum situation is to have an individual who is very familiar with the aquatic plant situation in a particular water body to interpret the imagery for that area.

(3) Standard visual photointerpretation procedures are considered for the present time to be the most cost-effective means of extracting information from the aerial photography.

(4) The most important aspect of applying aerial photography to detailed surveys is being able to plan the mission to optimize the imagery for the information desired. This means considering such things as climatic conditions, growth stage of the plants, water clarity, cloud cover, and time of day.

3. DEMONSTRATION PROJECTS

To test the operational procedure for detailed surveys formulated in the model and field studies, a large-scale demonstration project was planned. The site chosen was Lake Marion, South Carolina, a part of the Santee-Cooper project of the South Carolina Public Service Authority. The surface area of Lake Marion is estimated to be approximately 400 sq km, and the principal noxious aquatic plants are Brazilian elodea (*Egeria densa* Planch) and water primrose (*Ludwizia* spp.).

The Georgia Air National Guard flew the photo missions of the study area. Two missions were flown over upper Lake Marion, one in November 1976 and one in June 1977. The imagery was acquired at a scale of 1:20,000. The imagery products received at WES were 12.7- by 12.7-cm false-color infrared transparencies on a continuous roll.

Figure 1 is a typical example of the imagery acquired from the photo missions at Lake Marion. Examples of the appearance of aquatic plant infestations are noted on the image.

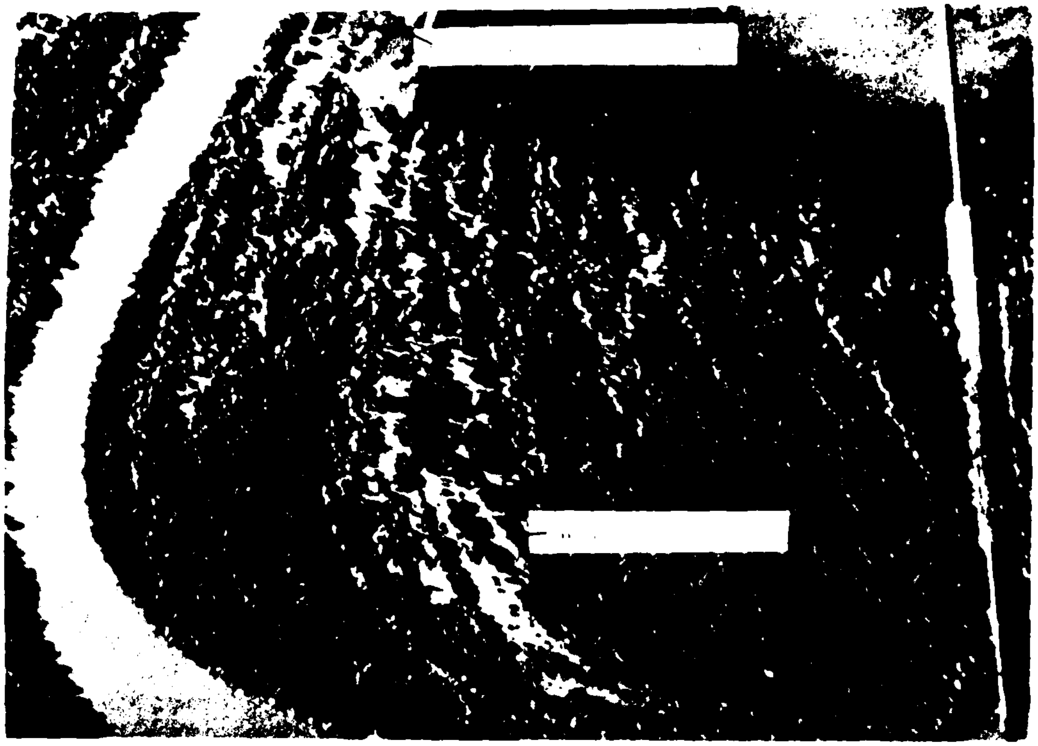


Figure 1. Black-and-white reproduction of a typical false-color infrared aerial photograph used for mapping aquatic plant infestations at Lake Marion, South Carolina

A technician skilled in aerial photointerpretation, but not in aquatic plant characteristics, examined the images and transferred the location and outline of the various plant assemblages to a 1:24,000-scale base map. The technician received interpretation keys from a botanist who had made at least one ground visit to the lakes being mapped and had collected ground truth data on the target species. A map of the aquatic plant infestations of the lake was produced from each set of aerial photographs. The area infested by each species was measured and recorded. Figure 2 is an example of the map produced for a portion of Lake Marion, South Carolina, and shows the areas of aquatic plant infestations outlined and coded by species.

Shortly after the mapping exercise was finished, the maps were taken to the respective lakes and compared with actual conditions, that is, the species composition and areal extent of the various plants. The most prevalent error on the maps was in delineation of submersed aquatics. Although most patches of submersed aquatics were correctly identified by species, the submersed patches in reality usually covered a greater area than that detected on the color infrared aerial photography. The discrepancy tended to vary with the depth and clarity of the water. In clear water the errors were very small; however, as the depth of the water above the plants increased and the clarity of the water decreased, the errors increased. The surface aquatic plant infestations were mapped accurately and with a notable level of detail. Table I provides a comparison of the corrected imagery-derived and ground-estimated areas for the lake. Values for each imagery coverage are presented to show changes with season.

Examination of Table I shows that the imagery-derived areas for water primrose at Lake Marion were quite close to the ground estimates. Egeria area values obtained from the two imagery missions were quite consistent, but low compared to the ground area estimates. This may be due to the inability of the interpreter to detect deeply submersed infestations of Egeria. The naiad (Najas sp.) area values from the November 1976 imagery agreed very closely with the October 1977 ground estimates. The June 1977 imagery derived estimates were quite low, because of the majority of the infestations being in deep water, or significantly below the water surface. Naiad characteristically remains submersed until later in the growing season.

The cost of producing a vegetation map from aerial photography of course varies with the areas imaged and the scale of the imagery. In general, the costs include the cost of film, the cost of the aircraft flight, processing of the film, collection of ground truth data, production of maps from imagery, and field verification of those maps. In addition to the size of the area to be mapped, the desired precision of the end product influences both the scale and the detail by which information is transferred to a map. Some guidance on general estimates of costs involved in producing maps such as that shown in Figure 2 is as follows:

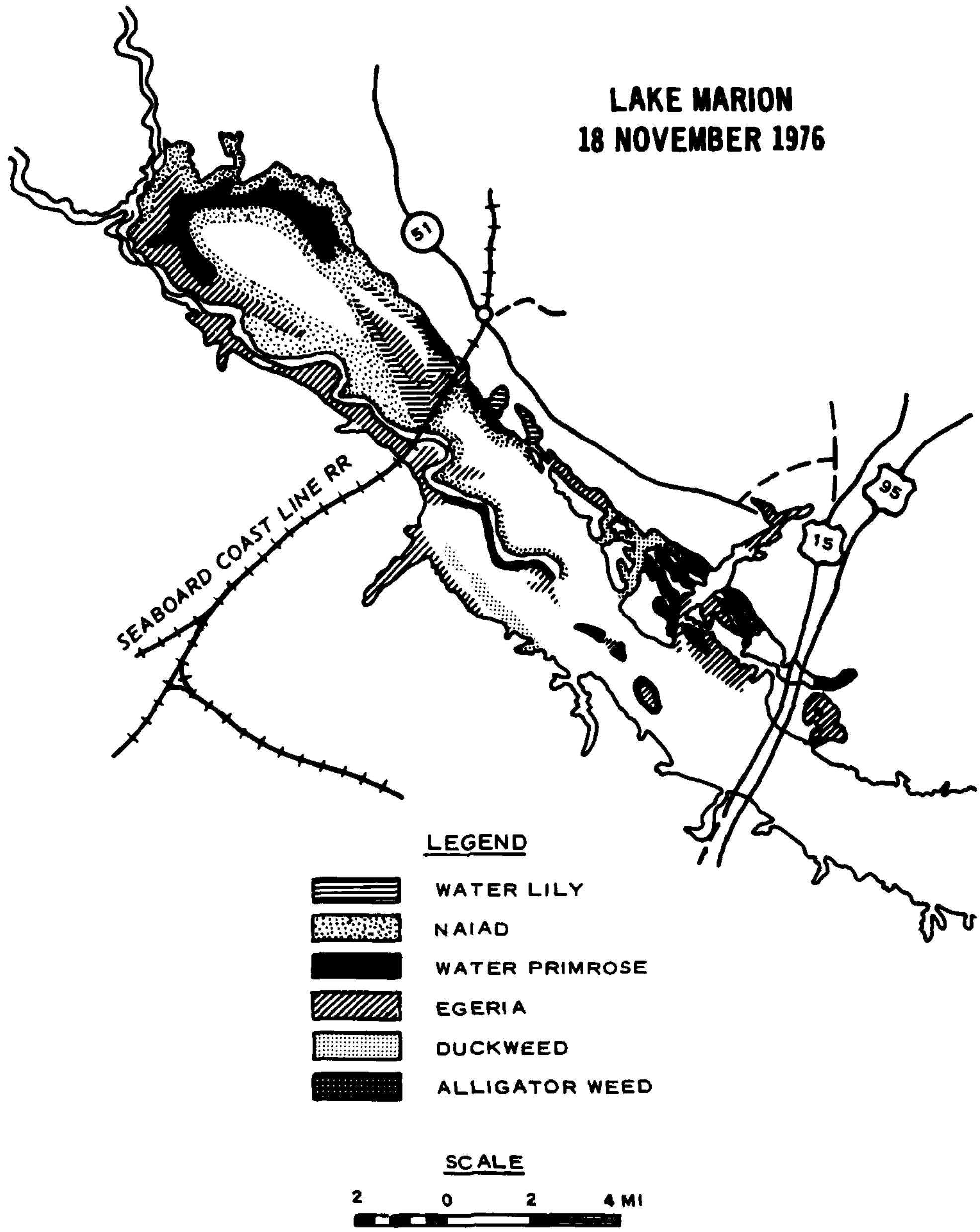


Figure 2. Example of an aquatic plant infestation map for a portion of Lake Marion, South Carolina

Table I. Comparison of Imagery Derived and Ground Estimate of Areas of Plant Infestation.

		Areal Coverage, km^2		
		Imagery Derived Estimate		Ground Estimate
Location	Plant Species	Nov 76	Jun 77	Oct 77
Lake Marion	Water Primrose	40.0	34.4	36.4
	Egeria*	50.0	57.1	83.2
	Naiad*	53.8	12.0	57.7

* Generally submersed.

a. Film. Color infrared film in a 12.7- by 12.7-cm format currently costs approximately $100 per 100-ft roll. One roll was used for each mission at Lake Seminole. Film in a 23- by 23-cm format costs approximately $210 per 100-ft roll.

b. Aircraft flight. Costs of aircraft flights vary with the type of aircraft, distance from the aircraft's home base, and flight time necessary to cover the target area. For the studies reported herein, the equipment and services of the Georgia National Guard were supplied as a training mission at no cost; however, the cost of such a mission performed by private contractor might be estimated at $1,500 per mission.

c. Processing of film. Processing color infrared film to produce a continuous roll of positive transparencies costs approximately $1.00 per ft. Cost of processing the film for each mission was approximately $100.

d. Collection of ground truth data for imagery interpretation. Each of these field studies involved about three man-days of effort, a total of approximately $650.

e. Production of maps from imagery. After the film had been processed, each of the map sets required a minimum of five man-days to produce, costing approximately $1000.

f. Field verification of maps after imagery interpretation. This parameter depends on how much precision is required. When meticulous ground measurements are required, costs will increase proportionately. In the exercises noted herein, about three man-days were taken to check the maps at a cost of approximately $650.

Each aquatic plant infestation map for a 400 sq km water body will, thus, cost approximately $4,000, roughly $10 per sq km. The cost for similar products on larger water bodies would be slightly less per unit area, and slightly more on smaller water bodies.

ESTIMATING CROP DAMAGE BY USE OF COLOR INFRARED PHOTOGRAPHY

Paul D. Soyke

Corps of Engineers
Rock Island, Illinois

ABSTRACT

Color infrared photography is an efficient and accurate method of estimating crop damage due to flooding. It has many advantages over field surveys or black and white photography. The equipment and training necessary to obtain satisfactory results are minimal although more sophisticated techniques will allow for more extensive use of the product and its application to other uses.

BACKGROUND

In the past, the most common method of estimating acres flooded and resulting crop damage due to flooding has been to interview farm operators, to update historic information, or a combination of both along with black and white aerial photographs.

These methods all have problems associated with them.

* Interviews are time-consuming and expensive. They are also, as we have discovered, not as accurate as previously expected.

* Updating historic data does not allow for changes in land use nor can it do more than update any past mistakes or inaccuracies.

* Black and white photography has many limitations, including the inability to obtain coverage that is useful during the flood event and difficulties in interpretation.

The Rock Island District, in cooperation with the Iowa Geological Survey Remote Sensing Laboratory (IGSRSL), has analyzed the potential for using color infrared (Color IR) to obtain the data necessary to estimate crop damage for post flood reports and also for future studies. We have found that Color IR can produce results that are less expensive and more accurate than previous methods.

FLOOD BOUNDARIES

In 1972, IGSRSL began research to more accurately determine flood boundaries and experimented with several types of film to find those which would most easily define the limits of inundation. The result of this study was that Color IR film produced images that best defined the flooded area. This film has the capability of showing the inundated area as late as 24 days after the event under some circumstances. The film that has been most satisfactory for this use is Kodak 2443 Aerochrome infrared film. Characteristics of infrared radiation include the absorption of photographic wavelengths by water, the reduced infrared reflectance of wet soils and stressed plants, and the different reflective properties of materials. The near-invisible infrared band is superior to any of the visible wavelengths because almost all of the infrared wavelengths are absorbed at the water surface. Conversely, bare soils have a relatively high infrared reflectance. Thus, the tonal contrast of the infrared band is much greater than in any band in the visible spectral region.

Based on the research done by the Iowa Geological Survey, the Rock Island District began using Color IR in 1974 to obtain flood limits. Based on the exceptional results obtained by this method, we thought this same technique might have expanded applications. We specifically theorized that it could be used to determine actual crop damage.

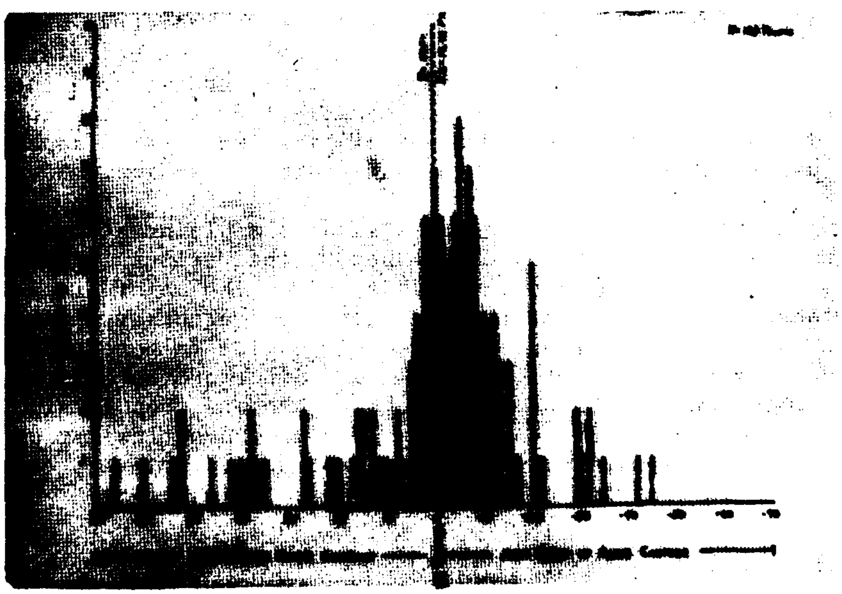
FLOOD DAMAGE

In June 1975, a heavy rainfall which caused a record flood on Squaw Creek and the Skunk River near Ames, Iowa, gave us the opportunity to test our theory. In cooperation with the Iowa GS, we obtained Color IR imagery of this event 4 days after the crest with the idea of analyzing the potential value of this film in estimating crop damage. The area had been photographed with black and white film at crest by the USGS so that we had a check for the actual limits. The area was flown again in early August and once more in late September. These later two flights were used to determine the response of the crops to the flood stress and the subsequent action by the farm operator. We later concluded that a flight 4 to 6 weeks after the flood might be all that is required along with the original flight to determine the crest. However, in limited cases or where more detailed information is desired, sequential photography may be valuable.

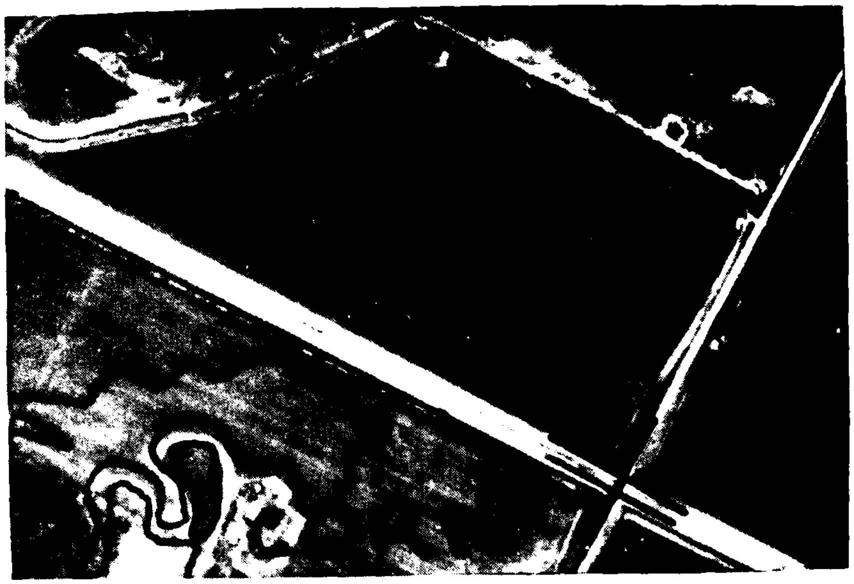
During August, the District made a field damage survey by interviewing the farmers in the flood plain, requesting information on acres flooded for each crop, yields expected for the damaged crops, and yields expected without flooding. This survey indicated that about 10,000 acres had been flooded in the study reach. Analysis from the photography, however, indicated that 20,000 acres had actually been flooded. Since we had previously depended on these interviews, the difference was quite a surprise to us. Further research indicated that the two basic factors in this large error can be attributed to the inability of the ground survey team to accurately identify all farms that had flood damage and the errors in the estimates made by the farmer in estimating the acres flooded as well as in estimating the amount of damage to the crop.

Contrary to our previous opinion, the farmers are not really very accurate estimators of crop acres flooded or of yields obtained from a specific plot. There are several reasons for this, but primarily, it seems that they do not keep the detailed records or measure the acres flooded to the degree necessary to provide the information. Aerial photography allows much more accurate measurement of areas flooded and crops destroyed than interviews do. It also allows for detection of acres damaged that may be unseen by ground inspection until actual harvesting.

A further check was made of the flood limits by surveying valley profiles and high water limits immediately after the flood crest. This resulted in confirmation of the photography. The area as interpreted by photographs was within 2% of that as determined by a survey using valley sections. With 133 reference points, the mean horizontal value was less than one-half foot. The vertical accuracy was also one-half foot. This then confirmed the potential of Color IR for obtaining water surface profiles. The 2% accuracy obtained is well within the limits of that required or obtainable by most other methods (see Figure 1).



The procedure for estimating the crop damage begins by delineating the flooded area and crop types on a transparent plastic. This is then overlain on the second set of photographs to show the flooded area in relation to the subsequent crop conditions. If only one set of photographs is used, the overlay is plainimetered to measure acres (see Figure 2). Although the delineations are not very obvious on the figure, the color transparencies show the differences well.



Although this research was primarily accomplished by the IGSRSL who are a team of highly skilled individuals in photogrammetry, we were concerned that the procedures to estimate the crop damage be relatively easy since trained personnel are not always available and we were not sure if an intense training program would be feasible. However, the total area flooded of 20,000 acres along 40 miles of river was mapped in two days by a summer assistant with only a 20-minute training session.

Using normal measuring techniques such as a plainimeter or area computer, the area flooded can be determined by the various land use classifications and crop types. In the area studied, the major crops are corn and soybeans. These were interpreted with a 90% accuracy after only a 15 to 30 minute training session. The identification is based on color and texture along with a basic field sampling. Since stereo coverage was obtained, this can also be used as a check when one crop is significantly higher than the other. Stereo coverage has many benefits for photo interpretation but is not necessary for this procedure. However, some accuracy may be lost in identifying crops without stereo capability.

Although the crop identification is subject to small errors, the economics of crop production in the Midwest tend to minimize the impact of these errors on the dollar value of the damage. Also the errors for large reaches tended to cancel out while they were significant only on small areas. When the crop had been completely destroyed and plowed under, these acres were distributed in relationship to the surrounding fields. Further training or experience and more extensive field sampling can reduce these errors substantially.

The yields are estimated by determining normal expected yields from the SCS office, from soil surveys, or if possible from your own samples. Interviews with farmers can be used, but our tests indicated that these were not always reliable. Once a determination of expected yields is made, this can be multiplied by the acres that were totally destroyed to result in total crop lost. Those acres that are totally lost are obvious on the later photography. The remaining acres will be those that were flooded but not totally lost. Obtaining expected yields from these damaged crops is a more difficult process. Basically it involves more guesswork than any of the previous estimates; but with practice and good field data, accuracy within limits of about 85% can be obtained. The process involves comparing the density and color of the plants that were flooded with those adjacent which were not, and estimating the yield by comparing the color and density and relating this to field data samples.

Although the correlation between interpreted yields and those obtained by interview was fairly low, the tendency of farmers to over or underestimate acres flooded and reduced yields tended to offset each other, thus resulting in some considerable descrepencies for statistical purposes. However, there seemed to be a consistency in these estimates that resulted in the interpreted total production estimated within reasonable limits. Actual field sampling using simple methods or interviews with local USDA officials should result in more reliable estimates.

Even though the yield estimates are not as accurate as we had hoped, the total production lost is in fact more accurate than the field interviews and with further research and experience some of the problems are becoming more defined and a more accurate procedure for determining remaining yields is being developed. The expansion of these techniques will no doubt result in further refinement and new methods that can make the procedure even more accurate and economical.

Use of Color IR in the Rock Island District since its initial development has resulted in average annual savings of about $4,000 over the previous interview methods. The savings have ranged from $3,000 to $14,000 for specific floods. In the event of a major flood on a large river, this procedure is not only cost effective, but obtains much more timely results and uses far less manpower.

SUMMARY

In summary, we have found that color infrared aerial photography is the best method of determining areas flooded in cropland areas and has real possibilities in determining actual crop damage. The low altitude photography can be obtained by normally available aerial contractors. Interpretation can be accomplished in a short time by inexperienced photo interpreters, and the crop types and yields can be verified by a field check of a relatively small sample of the population. This method with its limitations is still as accurate as other methods and promises, with further research, to be a much more reliable and efficient method than any other we have used. Equipment necessary can be as simple as an ordinary light table; however, somewhat more sophisticated equipment such as a Richards light table and zoom transfer scope is a definite asset.

We have not compared the results of our project with those obtainable by using electronic scanners or similar equipment since this is not available to most districts and requires a considerable investment as well as a skilled operator. We feel that our method gives acceptable results and is efficient and reliable for most uses.

BANQUET ADDRESS - A VIEW FROM SPACE

Harrison H. Schmitt
U.S. Senator (R-NM)
248 Russell Senate Office Building
Washington, D.C. 20510

Harrison H. Schmitt was born in Santa Rita, New Mexico on July 3, 1935, and raised in Silver City, New Mexico. He was educated in the public schools of Silver City where he graduated from Western High School. He received a Bachelor of Science Degree from the California Institute of Technology in 1957, and he studied at the University of Oslo under a Fullbright fellowship during 1957 and 1958. Schmitt earned a Doctorate in Geology from Harvard University in 1964.

After graduating from Harvard, Schmitt spent a year working on space-related projects for the U.S. Geological Survey in Flagstaff, Arizona.

In 1965, Schmitt joined the NASA Apollo program. As the lunar module pilot and geologist of Apollo 17, Schmitt landed on the moon in the Valley of Taurus-Littrow in 1972.

Schmitt was appointed NASA Assistant Administrator for Energy Programs in May, 1974. He resigned from this post in August 1975 and returned to New Mexico to enter the senatorial race. Schmitt was elected to the United States Senate as a Republican on November 2, 1976.

Schmitt serves on the Appropriations Committee; the Commerce, Science and Transportation Committee; and the Select Committee on Small Business.

Schmitt is a member of various scientific and professional organizations. He is the recipient of numerous professional and academic awards.

One of the things I've discovered not only in politics but in other activities is that the more you can associate yourself with the group to which you are speaking, the better. I was sitting here trying to think of all the direct and indirect associations I've had with the Corps of Engineers and the topics that you are dealing with and I'm happy to say they're too numerous to list, as you wouldn't be interested in most of them anyway. But, I would say that I cut my teeth, professionally so to speak, as a senior out of high school working with the U.S. Topographic Division of the U.S. Geological Survey up in northern New Mexico where we were doing third order control for photogrammetry, and then not too many years after that used an old Fairchild Comparograph to make my own topographic map of a small area in Norway where I was doing some geology for my doctorate. Then I suddenly discovered the Corps of Engineers when I was directing the USGS programs dealing with roving vehicles that somebody might put on the moon, a great deal of testing was being done by the Corps, and then discovered that some of the maps that we took with us to the moon were produced by the Corps of Engineers through more modern techniques than I had been exposed to in those earlier years. I guess the place in my heart, however, that has its deepest penetration relative to the Corps' history at least and that has to do with a group called the Army Corps of Topographical Engineers. This was probably the closest precursor, the closest historical analogy to the astronauts who explored the moon of any group of people I have ever run into in my reading of history; a group of 26 West Point graduates in the natural sciences who were assigned to the Army expeditions into the American West in the quarter of a century just preceding the Civil War. And they did almost everything as natural scientists as well as Army officers with those expeditions that we were asked to do both during and after our missions to the moon. And those of you who have not studied that group of individuals I would strongly recommend that you do. A fascinating people. Freemont was the first. Probably the premier scientist of the group and the worst officer was LT Emory who came through my part of the southwest and New Mexico. So I had for many years followed or at least read of their exploits and read their reports and found it fascinating to see how closely analogous their activities were to those of the astronauts on the moon. With this background and for many other reasons, I have maintained a very strong interest in remote sensing.

During the first days of the 96th Congress I introduced the bill numbered S-212, The National Aeronautics and Space Policy Act of 1978; and as this was proposed, it contained many provisions dealing with space policy, one of which was the creation of a World Information System. And, as implementing legislation for that part of the Act, I also introduced the Earth Resources Information Satellite Corp. Act, S-875. If this bill were enacted into law, this second bill which I will call "The EARTHSAT Bill" on occasion, it would provide the statuatory basis for the creation of a commercial operational service for the gathering and dissemination of earth resources information.

The terms earth resources information and remote sensing are gradually becoming part of our everyday vocabulary although hardly household words. Remote sensing is an art and science that has been around for a long time, first and foremost, of course, in the form of man's eyes. We are very far from duplicating with instruments and systems the capabilities of those eyes and their unbelievably sophisticated data processing system that we call the brain. However, we have learned over the past decade to vastly extend the reach of our eyes through satellites, high altitude aircraft, increased knowledge about the earth and its resources, an explosion of technology and the sensing of the response of natural materials to electromagnetic radiation and an unbelievable expansion of data processing techniques. These technologies have all contributed to making visible and useful that which was previously hidden and wasted. It is this extension of our ability to use our eyes and brain to observe, integrate, synthesize, interpret, and apply that which we have come to know as remote sensing.

The broad scale use of the unique view of the earth offered by satellites began in the 1960s with the development of telecommunications and satellite systems. The obvious success of these efforts culminating in COMSAT, INTELSAT, and the World Weather Watch is based on the long established need for global communications and weather information. In addition, there was in existance at that time, a long established institutional base to use telecommunications and weather information. The perception of need for earth resources information and the institutional base to serve that need has developed slowly in spite of the obvious potential of such information. I suspect that after your seminar today and at other times it may seem to you that this development has not been slow but when you are in a political position looking out over the multitudes to see how many of them will stand up and say, "Yea, we need an operational resources system."; the development has in fact been slow, but now as slow as many would like to lead you to believe. Unlike telecommunications and weather data, earth resources information was not in general use prior to the space age since it was not available, except in the form of more or less standard aerial photography.

With the existence and ever broader use of information from the LANDSAT and SEASAT types of systems and the increasing understanding of techniques and value of data from such systems the time has come, I believe, to develop an operational earth resources information service. Commercial and government applications for the information from an operational system have been well demonstrated by you and others. The hearings of May and June in 1977 before the Science Technology and Space Subcommittee upon which I'm the ranking Republican member began to show the viability of an operational earth resources system. Support has grown since the introduction of the bills that I've cited before and in response to the subcommittee hearings that were held at that time. In response in particular, the following major areas for the utilization of satellite capabilities can be cited along with, of course, all of those that you've heard about in this conference. Improved agricultural information, production, and worldwide marketing based on the identification and repetitive monitoring of crop yields, crop damage, and infestations. Improved rangeland management and production based on repetitive evaluations of vegetation, soil, water, and livestock characteristics. Improved forest products production based on identification of types and suitability of trees and on repetitive monitoring of change due to natural and human effects. Improved water resources management through direct and repetitive measurement and evaluation of surface water and by geological evaluation of soil and subsurface features of hydrological significance and by rapid evaluation of engineering parameters related to development projects. Improved targeting of favorable localities for mineral and energy exploration and for expanded production based on more rapidly available and higher quality geologic maps, topographic maps, and on the sensing of various chemical elements due to their influence on vegetation, mineral, soil, textural or thermal characteristics. Improved repetitive identification of adverse changes in urban and rural situations due to human habitation, improved monitoring of natural and artificial environmental changes based on repetitive evaluation using a wide variety of techniques and finally; improved identification, evaluation, and monitoring of marine and coastal resources. That, of course, is only a partial list but I think includes most of the kinds of things that are possible to do.

There is one more great potential benefit of remote sensing technology that unfortunately is often forgotten or is considered with only short term insight. This is the bridge of long term friendships and mutual benefit that can be built between the United States and the emerging nations of the world upon the foundation of space technology. The decade of Apollo and SKYLAB have convinced many peoples and their leaders that through space technology and our help to use that technology they can bring themselves into the twentieth century. My travels around the world since the Apollo 17 mission have shown me that these peoples, particularly those in the developing countries now believe that they can participate in the future alongside the present industrialized community of nations. Our challenge and those of our western allies is to provide the basis for partnership rather than for confrontation. The potential availability of remote sensing and communications satellite systems during the next several decades is one of the basic ingredients of rapid international advancement and of the mutual interdependence the world so desparately needs. With access to these systems the chronic problems of resource management and education can be solved by the emerging nations. Agricultural monitoring and predictions as well as engineering projects and explorations for energy and minerals can be considered possible, in fact probable, with the establishment of the appropriate national and international institutions. Once established, operational programs exist in telecommunications and weather forecasting both nationally and internationally. The presently operational components of a world information system are manifested respectively in the COMSAT, INTELSAT, and World Weather Watch activities. These two areas of activity illustrate several of the organizational and management options available in the development of other components over more broadly based world information systems including remote sensing and earth resources information gathering. COMSAT, for example, is a publicly held regulated corporation with many of the advantages of being part of our competitive stockholder-controlled free enterprise system. In addition, because of its unavoidable international activities COMSAT must submit to federal guidance in foreign policy related matters and other regulatory concerns. After 16 years this innovative commercial arrangement appears to be working very well. INTELSAT, on the other hand, is a unique user-based international management organization for global satellite telecommunications to which COMSAT is our designated national representative. COMSAT is also the current operational manager of the INTELSAT system under contract to the organization as a whole although this relationship is currently under discussion. INTELSAT's success is a result of its national members being a vested interest as users in the successful management of a truly international, technical, and societal resource that is truly the common heritage of all mankind. This model could be much more widely applied in other space related activities as well as in areas such as the management of international waterways, deep sea resources, and international nuclear waste, if that becomes necessary. A different noncommercial multinational arrangement approach has been applied to the World Weather Watch. In this organization the United States, the Soviet Union, Japan, and the European community have or will have made available to the world the weather information gathered by their nationally controlled satellite system. This arrangement is coordinated by the World Meteorological Organization and the International Council of Scientific Unions. This type of arrangement appears to work best when it is generally agreed that the information made available by technology should be generally disseminated without restriction because of its immediate value to the health and safety of large numbers of human beings.

The technology and perceived uses of earth resources information collected from space and aircraft have advanced to the point where the organization of operational entity is warranted. The only question is, under what auspices should such an entity be created. Commercial, institutional, state and local government users of such information all have testified to this fact on numerous occasions before the committees of the Congress. In addition, the data from the developmental NASA LANDSAT system now in operation is in ever increasing demand. Other nations are beginning their own developments clearly with an eye toward marketing earth resources information on a worldwide scale. Thus, the United States must come to grips with how it will reap the economic and political advantages of the technology it has introduced to the world. As with telecommunications the potential advantages in the use of earth resources information lie in both the commercial and public sectors. This fact suggests that the operational management of an earth resources information system should be organized as was COMSAT as an investor-owned regulated corporation modeled after that successful experience with COMSAT in the telecommunications field. The Earth Resources Information Satellite Act, S-875, that I mentioned earlier closely parallels the statuatory structure and the successful experience of COMSAT. This bill establishes a policy to create a commercial earth resources satellite corporation as soon as it is possible to do so. The bill would provide the widest possible industry and public use of the system on a nondiscriminatory basis. EARTHSAT would be a private corporation regulated by the Federal Communications Commission. The role of the FCC would be to insure effective competition, that of a referee, and to guarantee equitable opportunities are provided all investors, contractors, and consumers. Additionally, the FCC will make certain that the opportunity to purchase earth resources data under just prices will be available to all persons and organizations. Other FCC regulatory responsibilities would include establishing internal management controls proscribing accounting standards and regulations and authorizing the issue of capital stock. It is recognized that the FCC will have to expand the scope of its present responsiblities to encompass the regulation of earth resources information services but it is our belief that that is only a modest expansion because of the nature of the technologies involved. It would be, however, the responsibility of the National Aeronautics and Space Administration, NASA, to advise the FCC on technical matters just as they do today in telecommunications as well as furnishing launching services for the corporation on a reimbursable basis. NASA's experience in setting up COMSAT will also be of assistance in the operation of this new information system. It would be essential for NASA to continue to conduct research and development to refine the capabilities of an information system in space. We neglected to continue to do this for some time in communications we now have realized that mistake and NASA is moving back into the communications R&D field. NASA will be involved with the initial planning and development of the corporation. It also has the responsibility for coordinating activities of various governmental agencies that would be involved with or benefit from the EARTHSAT Corp. International aspects of the availability of data will also be under the supervision of NASA in cooperation, of course, with the State Department. EARTHSAT would be composed of a 17 member board of directors, three of its members would be appointed by the President. The Departments of Agriculture, Commerce, and Interior and the National Association of State Governors would each appoint one member and 10 members would be elected by the stockholders. The corporation will be authorized to issue stock which will carry voting rights. It is the intent of this act, should it become law, to encourage the widest participation in the corporation by the American people. The EARTHSAT Act would authorize the corporation to market raw and preprocessed data on earth resources, own and operate the earth resources satellites, own and operate ground receiving stations, and own and operate information distribution centers for the provision of raw and preprocessed data. We would specifically remove the value added data from the corporation. More importantly, in order for this corporation to be successful it must be responsive to public needs and national objectives relating to resource information services.

I have gone into some detail about this because it is an issue of some controversy at least within the Commerce Committee. There are some who believe that an operational earth resources system should be left within the federal government. It is my belief that if we do that we will never or at least very, very slowly realize the potential of earth resources information for solving problmes and for providing service not only to Americans but also to all the world. The direction that I have described that is of the creation of an investor-owned corporation is part of what I feel is an aggresive policy that reflects our fundamental destiny in space, our destiny as a people and as part of western civilization.

You realize that we can develop the technology to achieve these goals and thereby fulfill that destiny that many of us foresee and I think many, many young people foresee for us. What is needed is a policy of support for such activities. This is what I want. As James Mitchner told us in February at hearings on the future space policy of this country, I would like to quote his remarks, "But I also believe that there are moments in history when challenges occur of such a compelling nature that to miss them is to miss the whole meaning of an epoch. Space is such a challenge. It is the kind of challenge William Shakespeare sensed nearly 400 years ago when he wrote, 'There is a tide in the affairs of men which taken at the flood leads on to fortune; ommited, all the voids of their life is bound in shallows and in miseries.' On such a full sea we are now afloat and we must take the current when it serves or lose all our ventures."

Ladies and gentlemen, the greatest of all accomplishments that we can achieve other than the survival of freedom on earth is to assure in our lifetime the destiny of free men and women in space. The realization of these two accomplishments may well have been inexorably established by the previous events of our times.

REMOTE SENSING APPLICATIONS GUIDE

Lewis E. Link, Ph.D
U. S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

ABSTRACT

The Corps of Engineers Remote Sensing Applications Guide has been completed and the first edition will be published as Engineer Pamphlet 70-1-1. Although prepared as a central comprehensive reference document and source of guidance for application of modern remote sensing to Corps engineering and environmental data acquisition tasks, the guide is appropriate for virtually any user. This paper gives a brief overview of the organization and content of the Remote Sensing Applications Guide with emphasis on the major topical areas covered and types of reference information included.

1. INTRODUCTION

Since the 1930's, remote sensing has played an increasingly important role in the Corps of Engineers. Initially, aerial photography was used as a tool in planning construction projects. New and more complex data needs have surfaced to meet the needs of Corp missions in such areas as regulatory programs, environmental impact assessment, evaluation of nonstructural alternatives in river basin planning, and real facility management. Modern remote sensing techniques are technically and operationally capable of meeting some of these data acquisition needs in a very cost-effective manner.

Advances in sensor technology, data processing, and analysis procedures have added new dimensions to remote sensing capabilities. These plus the increased sophistication of data needs dictated the need for a Corps remote sensing applications guide; a single document that can serve as a compendium of remote sensing for the user, comprehensive in content but simplistic in presentation. The first edition of this document is now completed and will be published as Engineer Pamphlet 70-1-1.

The Remote Sensing Applications Guide provides managerial and technical guidance for developing effective uses of remote sensing within the Corps of Engineers. The content of the guide and its appendices are designed to span both civil works and military facilities management applications by assisting the user in:

a. Identifying, planning, and conducting remote sensing application efforts.

b. Locating relevant remote sensing imagery data, expertise, and services internal and external to the Corps.

c. Acquiring an understanding of remote sensing fundamentals.

The Guide is organized in three parts as follows:

a. Part I: Planning and Management Guidance

b. Part II: Technical Guidance

c. Part III: Supporting Appendices

These parts are published as individual volumes to facilitate handling, and placed in a looseleaf, three-ring binder for ease of use and expedient update when necessary. Parts I and II are divided into chapters and the chapters into sections. Part III is simply a collection of the individual appendices. Figures 1 and 2 graphically illustrate the internal structure of the chapters in Parts I and II, respectively, to the section level. Figure 3 graphically displays the contents of Part III. The contents of each part is discussed below.

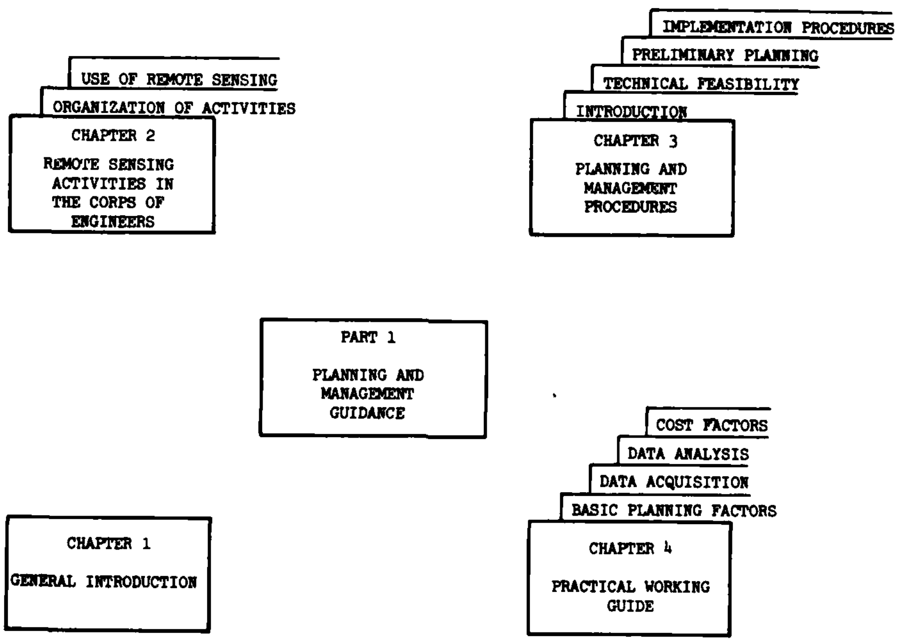


Figure 1. Structure of Part 1, Planning and Management Guidance

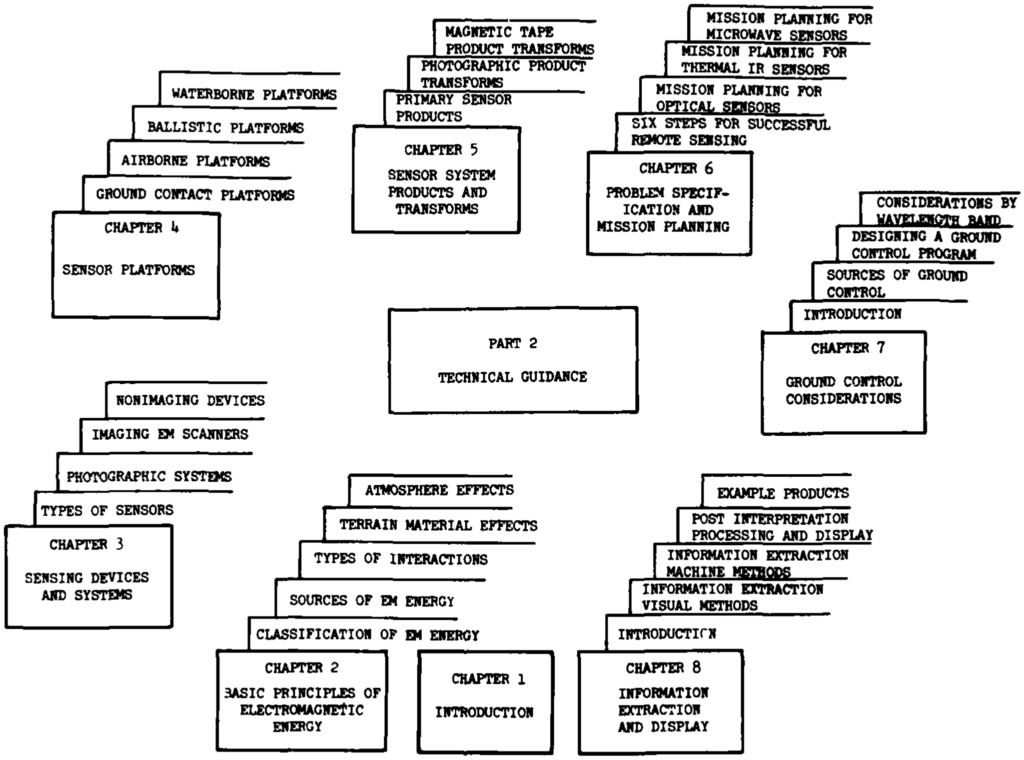


Figure 2. Structure of Part 2, Technical Guidance

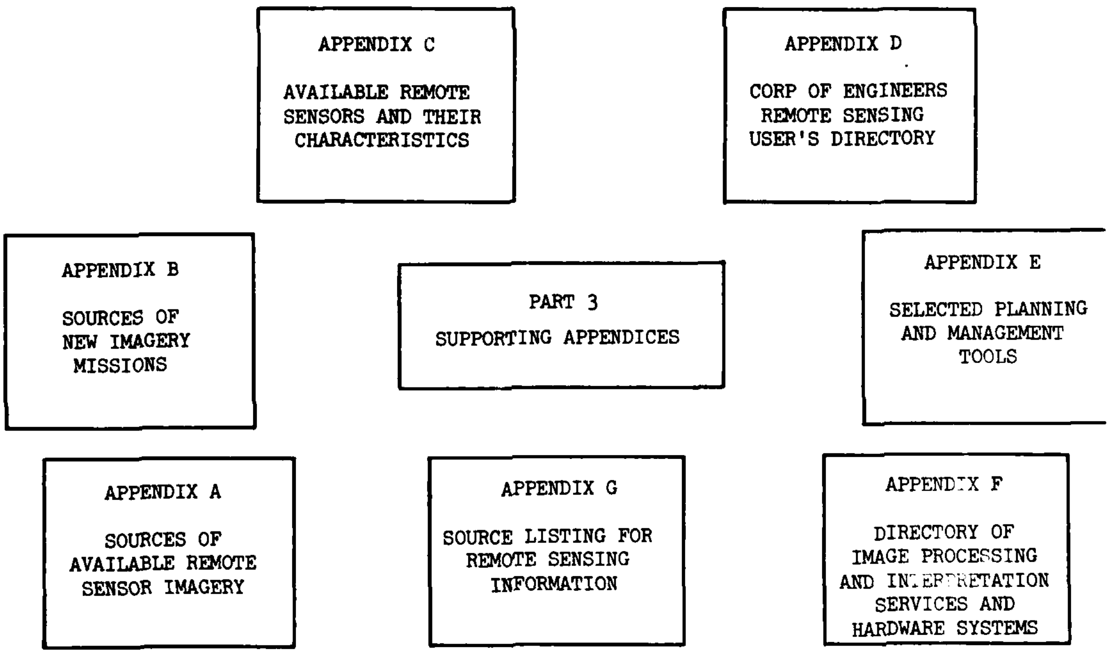


Figure 3. Structure of Part 3, Supporting Appendices

2. CONTENTS OF APPLICATIONS GUIDE

Part I

Part I has two functions. First, current Corps remote sensing activities are summarized from organizational, functional/disciplinary, and applications perspectives. This discussion is complemented by a comprehensive directory of remote sensing activities conducted at Corps Division, District, and Laboratory offices (Appendix D). In Chapter 2, concise state-of-the-art summaries are provided for selected disciplinary functional areas.

Chapter 3 presents procedures for assessing the technical feasibility of using remote sensing for a given data acquisition problem, a framework for preliminary planning of a remote sensing program to establish the suitability of a specific approach in satisfying project requirements, and procedures for establishing specific tasks, responsibilities, and schedules via a work plan. Flowcharts are provided for systematic execution of the procedures described, as well as example preliminary and final work plans.

Finally, Chapter 4 presents practical guidance for the user of remote sensing. The information included supports the guidelines presented in Chapters 2 and 3. Specific items addressed include problem definition, data requirements and how the data can be acquired, methods for analyzing the data, and procedures for determining costs. Each section is supplemented by numerous examples of remote sensing imagery that illustrate the information discussed in the text. This chapter is supplemented by Appendices A, B, C, E, F, and G which provide details on specific topics discussed in the text.

Part II

Part II is a basic discussion of all technical aspects of remote sensing. The individual chapters were designed to be used independently if desired, but together they provide a logical progression through the major technical areas relevant to remote sensing applications. Emphasis is on simplicity, and equations are avoided whenever possible. Chapter 1 introduces the content of the following chapters.

Chapter 2 provides a basic introduction to electromagnetic energy and its sources and interactions. Information is given on the effects of specific terrain materials on reflected and radiated electromagnetic energy and the effects of atmospheric conditions on the propagation of electromagnetic energy.

Chapter 3 outlines the different types of remote sensing systems available and discusses their basic methods of operation. The discussion is divided into photographic systems, imaging scanner systems, and nonimaging devices. The section on imaging scanner systems includes optical, infrared, and microwave scanner operation. The section on non-imaging systems concerns radiometers and distance measuring devices. The information presented is general in that it does not address specific sensor models. Appendix C provides supplementary details on specific sensor systems.

Chapter 4 provides a brief summary of the various platforms available for remote sensing. Emphasis is on the form and characteristics of the platforms and the constraints imposed by the platforms on the performance of remote sensing systems.

Chapter 5 concerns the types of products that result from conventional remote sensing systems. A distinction is made between primary and transformed products. Primary products (those directly available from the sensor) discussed include photographic products, magnetic tapes, and real time displays. Transforms (methods to make a primary product easier to interpret, or more compatible for producing the desired end product) are discussed for photographic and magnetic tape products. For photographic products, transforms for scale, geometry, optical density and contrast, color, mosaicing, and digitization are discussed. Procedures for scale changes, rectification, density slicing, contrast modification, image combination, edge enhancement, and filtering are discussed for digital data. Electronic techniques and coherent optical processing are discussed for analog data.

Chapter 6 provides information and guidance for planning remote sensing missions. Emphasis is on using the most cost-effective system that will provide the needed data in a form compatible with the user's capabilities for generating the final product. Guidance and supplemental information are given to help answer the questions:

<u>a</u>. <u>What</u> sensor should I use?

<u>b</u>. <u>When</u> should I acquire the imagery?

<u>c</u>. <u>How</u> should I fly the mission?

The discussion is divided into sections on mission planning for optical, thermal infrared, and microwave sensors. Tabular and graphical aides are used to portray information whenever possible, and considerable data are included on the properties of earth materials. This chapter is supplemented by Appendices C and E and can be used in conjunction with Chapter 4 of Part 1.

Chapter 7 summarizes ground control considerations. The diversity of information needs is covered in conjunction with imagery information content and the function of ground control. Sources of ground control information are outlined ranging from existing data to field collection. Guidance is given for designing a ground control data acquisition program

This guidance includes factor selection, sample distribution, site selection, accuracy and precision, and temporal dependences. Finally, specific guidance is given on the types of ground control data most relevant to the information content of remotely sensed data acquired in the various wavelength bands.

Chapter 8 outlines methods for extracting information from remote sensor imagery and postinterpretation processing and display of the data to achieve the desired end product. Both visual and machine methods are discussed. Under visual methods, stereoscopic viewing parallex, densitometry, feature extraction for interpretation keys, and interpretation of photographic, thermal infrared, and microwave imagery are discussed for acquiring information on vegetation, wildlife habitat, surface geometry, soils, bedrock, atmosphere, hydrology, pollution, and cultural features. The discussion on machine methods covers image geometry and resolution considerations, methods to determine features for classifying imagery (supervised and unsupervised), and interpretation techniques. Examples are given to illustrate the types of products that can be obtained. Imagery interpretation seldom produces the final product. Guidance is given for postinterpretation processing and display of information. Specifically, the basic types of interpretation products, basic problems faced, equipment requirements, and data manipulation procedures are covered. The last section gives examples of studies using remote sensing data to solve Corps related problems. Examples are presented for Landsat, thermal infrared, and aerial photography applications.

Part III

Part III is comprised of the appendices shown in Figure 3. Appendix A provides a tabular summary of Federal, state, and Corps of Engineers offices that have imagery available upon request. The tables include types of imagery, scales, products available, costs (when known), and appropriate addresses.

Appendix B provides a tabular summary of Federal civilian agencies and military units, state agencies, academic institutions, and private companies that have remote sensing data acquisition capabilities. The tables summarize the type aircraft and sensor systems available, costs (if available), and appropriate addresses.

Appendix C is a tabulation of available remote sensors and their general characteristics. Tables are included for aircraft photographic systems, aircraft infrared scanners, aircraft multispectral scanners, aircraft side-looking airborne radar, spacecraft photographic systems, spacecraft infrared scanners, spacecraft multispectral scanners, spacecraft vidicon systems, available films, and costs of aerial film processing and reproduction.

Appendix D is a user's directory for Corps of Engineers remote sensing applications. The directory is comprised of six sections which cover Corps of Engineers Remote Sensing Coordinators and Remote Sensing Committee members, indicies of remote sensing data uses within the Corps, and a summary of remote sensing work ongoing at the Corps' laboratories. The indices of remote sensing data uses are presented by major organizational elements in the Corps, by selected types of applications, by specific Corps-related functional areas, and by disciplines. All information presented is cross-referenced to allow the user to make inquiries for more information if desired.

Appendix E is comprised of selected information and tools to assist in the planning and management of remote sensing programs. Blank preliminary and final work plans are provided along with guidelines for requesting or contracting remote sensing missions and a nomogram for predicting photographic system performance. The nomogram allows the user to prejudge which film-filter combination will perform best for a specific data acquisition problem.

Appendix F provides listings of image processing and interpretation services, image processing hardware systems, and image processing software systems.

Appendix G is a listing of sources of basic information on remote sensing. The categories covered include abstracts and bibliographies; atlases, stereograms, photo interpretation keys and picture books; history journals and periodicals; photogrammetry, stereoscopy, and image quality; symposia proceedings; source material; and text books and documents.

3. SUMMARY

Although the Remote Sensing Applications Guide represents a rather comprehensive treatment of many aspects of remote sensing, there remain topics that deserve more attention. When appropriate, sources of additional information have been cited in the text. The three parts were designed to be used individually or in concert depending on the user needs. The same flexibility has been attempted for the individual chapters or appendices in each part. As such, the Guide can be a ready reference, a source of specific guidance on a broad topic such as mission planning, or a nonmathematical digest of the ABC's of modern remote sensing. The contents have been purposely generalized, whenever possible, to provide a framework for applying remote sensing to a broad range of data acquisition problems. Guidance is given for filling in that framework for specific problem types, but the actual "filling in" must be accomplished by the individual user to adequately consider the unique aspects of his data acquisition problem. The Remote Sensing Applications Guide should be considered the first edition in an evolutionary progression of aides to assist the Corps in applying modern technology to meet its ever more challenging data acquisition needs.

MISSION AND RESPONSIBILITIES

OF THE USGS EROS DATA CENTER

By
Donald G. Orr and Donald F. Carney
U.S. Geological Survey, Sioux Falls, South Dakota

SUMMARY

The Earth Resources Observation System (EROS) Data Center is administered by the U.S. Geological Survey for the Department of the Interior. The Data Center was established in 1972 at Sioux Falls, S. Dak. to serve as a principal dissemination facility for Landsat and other remotely sensed data. The Center provides public access to those data to both U.S. and non-U.S. users and provides training and user assistance to further the use and applications of those data to resource management problems.

Data holdings at the Center presently include about 1,300,000 Landsat images and 9,000 scenes of Landsat data on computer compatible tapes provided by the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC); over 50,000 Skylab, Apollo, Gemini manned spacecraft images; more than 1,400,000 aerial photographs from the NASA aircraft program; and some 3,330,000 Department of the Interior aerial mapping photographs.

At the heart of the EROS Data Center is a central computer complex that stores information about data holdings, performs searches for data covering specific geographic areas, and serves as a management tool for the entire data production and sales process. The computerized data storage and retrieval system is based on latitude and longitude and includes such information as image quality, cloud cover, and type of data (that is, Landsat images, Landsat computer compatible tapes (CCT's) high-altitude aerial photographs, etc.). A customer may query the computer as to data availability by specifying a geographic point location, a rectangular area bounded by latitude and longitude, or a polygon of up to eight sides. Based on the geographic area, quality and cloud cover constraints, and type of data requested by the customer, a computer search produces a listing of available imagery from which a final selection can be made. Inquiries can be made through terminals at the Data Center or through a remote computer terminal network which links the Center's computerized information file to a number of U.S. Government offices, the National Cartographic Information Center and its regional offices and State affiliates, and some commercial users.

Depending on data types, products are available in color or black and white photographs, in sizes from 16 millimeter through 40 inches, and as 9-track computer compatible tapes in 800 or 1600 bits-per-inch formats. In addition, data catalogs and specialized computer listings are available upon request. Prices for these products are available from User Services, EROS Data Center, Sioux Falls, South Dakota 57198.

Custom processing to specified scales, formats, and processing criteria is available from the Data Center. These services normally require longer periods of time for completion, and the price is three times the standard price for the product. In addition, a priority system for expedited delivery of standard products is available whereby products will be shipped within 5 working days from receipt of an order that is valid for a charge at three times the normal rate.

Through July 1979, the Center has produced approximately 2.3 million copies of the more than 6 million images of the Earth's surface that are held at the Center. In addition, about 11,500 CCT's containing Landsat data were supplied to users.

Major improvements for handling and processing Landsat data have been made at the Data Center recently. During February 1979, a system called EDIPS (EROS Digital Image Processing System) became operational for processing Landsat 2 and 3 digital data. Radiometrically and geometrically corrected Landsat high density digital data rather than 70mm film are now received from GSFC. The digital data are processed through EDIPS, which applies preselected restoration techniques, and are recorded onto 241mm film by a high resolution laser beam recorder. Output products include film transparencies, paper prints, CCT's, and high density tapes. Custom processing and restoration specified by the user can be provided also.

The use of a domestic communications satellite to relay Landsat data from GSFC to the Center began in May to speed up the availability of data to users. In addition, foreign receiving stations have begun exchanging information about their Landsat data holdings with the Center. The files from the Brazilian and Italian stations have been integrated into the Center's computerized file, and the Canadian data will be added in the near future.

Another major responsibility of the Center regards training and technical assistance activities which are designed to integrate satellite and aircraft remote sensing technology into the programs of the Department of Interior, other Federal agencies, and other interested foreign and domestic groups.

Training in the form of formal workshops and courses are provided for resource specialists and land managers interested in remote sensing technology. Approximately 25 workshops are offered each year to about 500 scientists, both domestic and foreign. After 5 years of conducting 120 training sessions involving over 2500 participants, the Center has noted a shift in demand for training away from general, introductory remote sensing courses towards courses that emphasize specific disciplines or techniques. The Center also plans to involve qualified universities in presenting workshops on specific disciplines or techniques. These workshops will be offered to practicing professionals, through university extension programs.

As follow-on to the formal training opportunities, cooperative projects are conducted in which proven remote sensing technology is tested operationally to meet resource information needs and to obtain management acceptance. A state-of-the-art Data Analysis Laboratory is maintained at the Center to develop and demonstrate new capabilities in digital image analysis and processing technology and to support the Center's training and technical assistance activities. Also, research and development are conducted on remote sensing techniques and applications.

To increase user accessibility and efficiency in its training and technology transfer activities, the Center will open an office in Anchorage, Alaska, which will provide resource agency personnel in Alaska direct access to training and assistance in remote sensing technology. The Alaskan office, which will be fully operational in the fall of 1980 and staffed with scientists trained in different disciplines, will provide both manual and machine-aided analysis capabilities.

The EROS Data Center is dedicated to the advancement of remote sensing technology for Earth resource applications. The Center will continue to investigate and implement new techniques for providing higher quality data products in a more timely manner; reducing costs associated with data analysis; developing methods of merging data from different sources; improving remote sensing technology acceptance through training, cooperative projects, and applications research; and overcoming institutional barriers which inhibit and delay uses of important data sources.

TECHNOLOGY TRANSFER

MG E. R. Heiberg III
Director, Civil Works
Office, Chief of Engineers

This article is a condensation of Major General E. R. Heiberg's address on Technology Transfer given at the U.S. Army Corps of Engineers Remote Sensing Symposium held at the Sheraton International Conference Center, Reston, Virginia, on 29-31 October 1979. General Heiberg is the Director of Civil Works, Office of the Chief of Engineers. He is a 1953 graduate of the U.S. Military Academy at West Point and has been an engineer officer throughout his 26 years of commissioned service, holding positions of increasing responsibility both as an Army Commander (platoon, company, battalion) and water resource program manager (area, district, division engineer). In addition, he has taught political science at West Point, served in the research and development field, worked in the Executive Office of the President (twice), and served several years in the Pentagon. His last Pentagon assignment was as Executive to the Secretary of the Army, who is the civilian responsible directly to the President for all water resource development activities of the Corps of Engineers.

General Heiberg has earned three master's degrees, one from the Massachusetts Institute of Technology in civil engineering, and two from the George Washington University in international relations and in administration. He is a registered professional engineer in Louisiana, and belongs to several professional engineering associations. He has served in Korea, Germany, and Vietnam during his Army career, and has been assigned to three different infantry divisions as a combat engineer. He holds a variety of awards and decorations to include the Silver Star and the Distinguished Flying Cross.

General Heiberg was impressed by the Corps' representation at this symposium. Attendees represented all Corps' divisions, a majority of districts, at least one facility, and several laboratories. He also noted the good representation from outside the Corps -- people who share with us many of the same skills and needs with respect to remote sensing. Representatives were present from industry, universities, other federal agencies, and France.

"It is now time in this business of remote sensing and water resource applications to focus on what is being done today," General Heiberg affirmed. "Several years ago we had to focus on what we were going to do. We've come a long way in the last several years."

"During the last few days, you've been wrestling with the technology of remote sensing and the practical applications of the technology. Our interest and our knowledge of this technology has expanded significantly. Today, real progress is being made in our capability to apply remote sensing techniques to broad operational missions. In 1975, when I first got a handshaking acquaintanceship with the remote sensing challenge, we had many doubts about the future course of this technology. I'm not sure how many of those doubts still exist. We must not only further develop the technology that we have at hand, but we must also integrate that technology with the various disciplines operating within the agency. That's the cry again for the multidisciplinary approach.

"Sir William Osler, a 19th century physician, said, "*In science, the credit goes to the man who convinces the world, not to the man to whom the idea first occurs.*" Engineering, of course, is an extension of science, and I think that the comment certainly applies to the engineering aspect of our business. It isn't our job alone to convince the world of what remote sensing has to offer. But, what we are looking at offers a great deal of promise and we have found keys for applications. I would like to think that I work with all of you in convincing at least the Corps of Engineers of that promise. However, your problems remain in your district, and your division, and your laboratory, and maybe in your office if you work for me. In our efforts to fulfill remote sensing's potential as a powerful and functional operational took we have two kinds of tasks to accomplish: technical tasks as well as those tasks which grow out of interactions between the disciplines and the human institutions we represent. The technical tasks are difficult, but we have good evidence here that we can succeed in solving those. Either the Corps will solve those technical tasks or someone else will. Sometimes that means that we must invent the technology ourselves, but not only that, we must know where the rest of the world is. One way to know the state-of-the-art in remote sensing is to retain a place of leadership. Only by doing significant work in the remote sensing area, can we keep our fingers on all that's offered there. That's extremely important in this area where so much is happening so fast. NASA is doing an excellent job in research. I think everyone here recognizes and, I suspect, would agree with my statement that technology in this area is advancing at a fast pace."

He continued with other problems. "There are barriers in the development of user models. The user model can be defined as the algorithm -- the formula to follow -- that translates remote sensing for our business into a form directly usable by resource managers. Managers must be able to use it directly to make decisions. User models are difficult to build, perhaps, simply because they represent interfaces of actions more complex and varied than those taking place in the domains they connect. Without that user model, though, we cannot transfer application technology to the user. The user model has to be the bridge between the remote sensing system and the management decision that it is designed to influence.

"The institution is a barrier. It's often difficult to accept and adapt to change. The Corps is exposing the respective users -- the planners and the engineers -- to remote sensing while it is still on the threshold of the operational stage, making the simplest demand, it would seem, on the participating institution.

"During a visit I made yesterday to the Cold Regions Research and Engineering Laboratory (CRREL) we discussed the problem of compartmentalization. Even in our relatively small -- measured in Washington terms -- civil works side or the civil-military side of the Corps of Engineers, we still encounter problems interrelating between the laboratories, but even more so with the rest of the Army. Part of it gets back to compartmentalization, single minded focus, but part of it is also due to the fact that we have a continued human tenet 'not invented here'."

General Heiberg then discussed the benefits that the Corps and other government institutions can derive from remote sensing and the importance of considering alternatives in decision making. He noted:

a. Interdisciplinary analysis of remote sensory data leads to a more complete consideration of alternative methods for developing a project at the earliest stages of development. The use of remote sensory data provides a vehicle for developing and carrying on an interdisciplinary discussion of a project. If we don't have a full interdisciplinary discussion, it will show up in the lack of such data in the interpretation and alternatives developed.

b. Remote sensory data may give insights into conditions that we are now guessing at when we start developing a project.

c. Data can be developed quickly and at relatively low cost.

d. Presentation of this type data at public hearings could help overcome the loss of credibility that we in the water resource agency business seem to have suffered in the past few years as this country went through a great crisis coping with environmental issues.

"One of the more recent examples that perhaps many of you are intimately familiar with is the dam inventory program," General Heiberg said. "The program quickly got national attention and presidential attention, in the wake of the failures of the Teton and Kelly Barnes Dams. The result was a long-overdue national program that we were told to do in a hurry, and we did. This is one of the earliest system-wide uses of data collected by a satellite. It was not a demonstration but an application of our technology. We used LANDSAT to identify waterbodies which we then could investigate either through permit records or the state/county records and, if necessary, on-site inspection. Congress assigned the job -- approving the President's initiative -- less than two years ago, and we will complete much of it in a few months. We could have done this using aerial photos instead of satellites, but the program would have been a good deal more expensive. Certainly, it would have been more time consuming and effort consuming. All the districts are using LANDSAT, and no one has asked for an exception. LANDSAT has been well accepted throughout the Corps for this particular application.

"I remember well the experiments we did four years ago at the Ohio River Division. In fact, we were deep into the program right after I joined the division, and it was my first close-up look at the business of remote sensing and the needs and the potential applications of the interdisciplinary approach. Each of our districts had its own project, so it was a very good way to examine the possibilities from the context of the Ohio Valley. The efforts of the Engineer Topographic Laboratories (ETL) and the division combined training with the operational application, so we'd have both an experiment and potential of the practical application involved. We were trying to develop, apply, and document an effective procedure for using remote sensing and interdisciplinary analysis techniques in planning the development of civil works projects. As a reult, the Chief of Engineers requested that a plan be developed for increasing the operational use of remote sensing and multidisciplinary analysis throughout the Corps. He also suggested implementation of the methods through a series of operational demonstrations to be conducted jointly between ETL and the Engineer divisions. Some of those included were done by the various divisions - Cloptin Crossing Dam in Texas; fish and wildlife migration along the Missouri River, that the Missouri River Division is still wrestling with; and North Atlantic Division's Chesapeake Bay dredge material disposal project."

Concluding with his thoughts on the future of the Corps of Engineers and of the Nation, General Heiberg noted that every decade has been associated with a sense of imperativeness. From a water resources viewpoint, the imperative issue during the decade of the 60's was concern about our environment. In the decade that is just ending, he said, "We took that imperative of learning about the environment, and we as a nation did something about it." Court cases resulting from environmental laws and regulations are still pending that must still be resolved. He commended the Corps -- and recognized the credit given the Corps by others -- for adjusting to the 70's and the laws that came along with environmental awareness. He predicted that the imperative issue for the 80's and 90's would be the recognition of the problems of energy. "We will experience in the 80's something like the environmental challenge of the 70's as we learned how to deal with water quality in various environmental issues," he said. "It will require a great deal of work and adjustment for the people involved in the water resource business." General Heiberg stated that most energy solutions, except solar, are dependant on water resources, and put a demand of one kind or another on water resources. "During the 80's energy will have a significant impact for the people involved in water resources and the decision-makers of this country.

"Another imperative ahead," he said, "but becoming more important today is what some people call the "oil" of the United States. We have what OPEC has in the longer term. We have an ability and a knowledge and a geography and a situation which allows us to be the leaders in the world for producing agricultural products. If the 80's is the decade of energy, the 80's and the 90's are probably going to be the decades of recognition of our ability to feed the rest of the world. Again, agriculture, will be the cat whose tail is water resources. This is already fiercely apparent to decision-makers in the West and certain other parts of the United States. In the Northwest, this is brought home very clearly today with the competing demands for water resources in that area."

General Heiberg also stated that he would add another challenge to the major imperatives of energy and agriculture for the 80's and the 90's -- defense. "This country does not have the lead time for mobilization it has had in the past. We must be prepared to handle the defense challenges in a much different context dealing with the question of whom will be ready first and how much time we have available to get ready. Unquestionably, there are many challenges ahead in all these areas," he said. "But, this symposium has provided opportunities for amplification of new technologies to help decision makers solve water resource problems that come together with the challenges of energy and agriculture."

General Heiberg concluded, "I hope that you can help us go another step into integrating the available technology with the immense challenges confronting the Corps and the other water resource agencies, as we wrestle in the years ahead with the interconnected challenges of energy, agriculture, and defense. I hope this symposium has helped you become a better salesman in that area; we need help everywhere. And as I said to you, I promise that I'll continue to do my part to ensure that the senior decision-makers of the Corps are aware of what we've got here. I congratulate you on the successful program here, and I look forward to working with you in trying to make sure that we're doing our part to get this nation ready for the challenges and the promises of the 80's and 90's."

LIST OF PROPOSED ATTENDEES

NAME	ADDRESS
ADAMS, John	US Army Engr Dist, Buffalo 1776 Niagara Street Buffalo, New York 14207
ADAMS, Wes	US Army Engr Dist, Kansas City 601 East 12th Street Kansas City, Missouri 04106
*ANDERSON, Carl	US Army Engr Dist, Norfolk 803 Front Street Norfolk, Virginia 23510
ANDERSON, Larry A.	US Army Engr Dist, Huntington P.O. Box 2127 Huntington, West Virginia 25721
ANDERSON, Vernon	Photographic Interpretation Corp. Box 868 Hanover, New Hampshire 03755
*ANFANG, Robert	US Army Engr Dist, Saint Paul 1135 USPO & Custom House Saint Paul, Minnesota 55101
ARAKAKI, Stanley	US Army Engr Div, Pacific Ocean Building 230 Fort Shafter, Hawaii 96858
AREND, Roger	Photographic Interpretation Corp. Box 868 Hanover, New Hampshire 03755
BABBITT, John	US Army Engr Dist, Galveston P.O. Box 1229 Galveston, Texas 77553
BAILEY, Susan	US Army Engr Dist, Portland P.O. Box 2946 Portland, Oregon 97208
BALCH, Brad	Commandant G-WEP-3/TP-12 U.S. Coast Guard Washington, DC 20040

*Unable to attend

NAME	ADDRESS
BARCELLOS, Daniel	US Army Engr Dist, Sacramento 650 Capital Mall, Rm 6020 Sacramento, California 95814
*BATES, Roy	U.S. Army Cold Regions Research and Engineering Laboratory P.O. Box 282 Hanover, New Hampshire 03755
BECCASIO, D. D.	Dames and Moore Suite 700, 7101 Wisconsin Avenue Washington, DC 20014
BENEKE, Rodney J.	US Army Engr Div, Middle East P.O. Box 2250 Winchester, Virginia 22601
BERGEN, Lawrence	US Army Engr Div, New England 424 Trapelo Road Waltham, Massachusetts 02154
BIACHE, Andrew	Autometric, Inc. 5205 Leesburg Pike Skyline Rm 1308 Falls Church, Virginia 22041
*BLACKEY, Edwin A.	US Army Engr Dist, New England 424 Trapelo Road Waltham, Massachusetts 02154
BLYSTRA, Andrew	US Army Engr Dist, Chicago 219 South Dearborn Street Chicago, Illinois 60604
BOCK, Allen C.	Mark Hurd Aerial Surveys, Inc. 345 Pennsylvania Avenue, South Minneapolis, Minnesota 55426
BOLAND, Dr. D.H.P.	Bureau of Reclamation P.O. Box 25007 Denver, Colorado 80225
BOWEN, John W.	US Army Engr Div, Lower Mississippi Valley P.O. Box 80 Vicksburg, Mississippi 39180

NAME	ADDRESS
BROOKS, Paul	National Wetland Inventory Suite 217, Dade Building 9620 Executive Center Drive Saint Petersburg, Florida 33702
BROWN, Robert J.	HANDAR, Inc. 3327 Kifer Avenue Santa Clara, California 95051
BROWN, Roger A.	US Army Engr Div, South Atlantic 510 Title Building 30 Pryor Street, Southwest Atlanta, Georgia 31905
*BUCKELEW, Tim	US Army Engr Div, New England 424 Trapelo Road Waltham, Massachusetts 02154
BURGER, Thomas	U.S. Geological Survey National Center Reston, Virginia 22092
BUSH, Donald C.	Defense Mapping School Fort Belvoir, Virginia 22060
BUSHMAN, John	Department of the Army Office, Chief of Engineers DAEN-CWP-P Washington, DC 20314
CALIO, Dr. A. J.	Mail Code ETS-6 NASA Headquarters Washington, DC 20546
CANTERFORD, Dr. R.	Hydrologic Research Lab (W23) National Weather Service, NOAA 8060 13th Street Silver Spring, Maryland 20910
CEHELSKY, Dr. Marta	Mail Code ETS-6 NASA Headquarters Washington, DC 20546
CHEVREL, Madame Michele	French Embassy 2011 Eye Street, Northwest Washington, DC 20006

NAME	ADDRESS
CIESIESLKI, Steve	US Army Engr Dist, Chicago ATTN: NCCCO-RN 219 South Dearborn Street Chicago, Illinois 60604
CLYDE, Eric	SUTRON 1925 North Lynn Street Arlington, Virginia 22209
COLLINS, J.	U.S. Army Engineer Waterways Experiment Station ATTN: WESEN P.O. Box 631 Vicksburg, Mississippi 39180
*CONNERS, R. W.	Louisiana State University Environmental Engineering and Management Mechanical Engineering Division of Engineering Research Baton Rouge, Louisiana 70803
CONROY, Bill	General Electric Company 5030 Herzel Plaza Beltsville, Maryland 20705
CONOVER, Glenn	Labarge Electronics 1101 17th Street, Northwest Suite 910 Washington, DC 20036
CONVERSE, Hugh	US Army Engr Div, South Pacific 630 Sansome Street, Rm 1216 San Francisco, California 94111
COOK, Jim	US Army Engr Dist, Nashville P.O. Box 1070 Nashville, Tennessee 37202
COOPER, Saul	US Army Engr Div, New England 424 Trapelo Road Waltham, Massachusetts 02154
CORNWELL, CPT Mark	Defense Mapping School Fort Belvoir, Virginia 22060

NAME	ADDRESS
COTTER, Dan	Department of the Army Office, Chief of Engineers DAEN-CWE-E Washington, DC 20314
COUCH, Frank B.	US Army Engr Dist, Nashville P.O. Box 1070 Nashville, Tennessee 37202
COWAN, Samuel S.	US Army Engr Div, South Atlantic 510 Title Building 30 Pryor Street, Southwest Atlanta, Georgia 30303
CRYSTAL, Roger	US Army Engr Div, Middle East P.O. Box 2250 Winchester, Virginia 22601
DAHL, Thomas	Martel Laboratory Baltimore, Maryland 21203
DAHLBERG, Theodore	US Army Engr Div, Missouri River 12565 West Center Road Omaha, Nebraska 68103
DALLAM, William	General Electric Company Space Division 5730 Herzel Plaza Beltsville, Maryland 20705
DALTON, Robert	RD 1, Box 195 Sterling, Virginia 22170
DAVIDSON, Richard	Department of the Army Office, Chief of Engineers DAEN-CWE-S Washington, DC 20314
DENDROU, Stergios	Water Resources Engineers 8001 Forbes Place Springfield, Virginia 22003
DEUTSCH, Morris	U.S. Geological Survey EROS Program Reston, Virginia 22092

NAME	ADDRESS
DODGE, R. K.	US Army Engr Dist, Portland P.O. Box 2946 Portland, Oregon 97208
DOMURAT, George W.	US Army Engr Dist, San Francisco 211 Main Street San Francisco, California 94105
DONOVAN, Bill	Department of the Army Office, Chief of Engineers DAEN-CWP-P Washington, DC 20314
DRAKE, Marvin	US Army Engr Dist, New Orleans P.O. Box 60267 New Orleans, Louisiana 70160
DREYER, Ernest	U.S. Geological Survey National Center Reston, Virginia 22092
DROZD, David	US Army Engr Dist, Philadelphia Custom House - 2d & Chestnut Street Philadelphia, Pennsylvania 19106
DUKE, Dennis	US Army Engr Div, South Atlantic 510 Title Building 30 Pryor Street, Southwest Atlanta, Georgia 30303
DUMAS, Ray	US Army Engr Dist, Chicago 219 Dearborn Street Chicago, Illinois 60604
*DURA, Wayne	US Army Engr Dist, Omaha P.O. Box 103, Downtown Station Omaha, Nebraska 68102
*DUVALL, R.	US Army Engineer Dist, Fort Worth ATTN: SWFED-MF P.O. Box 17300 Fort Worth, Texas 76102
EHLEN, Judith	U.S. Army Engineer Topographic Laboratories ATTN: ETL-RI Fort Belvoir, Virginia 22060

NAME	ADDRESS
*ENABNIT, Dave	Engineering Development Lab (C61) NOAA/NOS Rockville, Maryland 20852
EPPARD, Ralph T.	Department of the Army Office, Chief of Engineers DAEN-CWO-N Washington, DC 20314
ERLANDSON, John	US Army Engr Dist, Seattle P.O. Box C-3755 Seattle, Washington 98134
*EVELYN, Joseph	US Army Engr Dist, Los Angeles P.O. Box 2711 Los Angeles, California 90053
EXNER, Michael L.	Synergetics P.O. Box E Boulder, Colorado 80306
*EYSTER, Gary	US Army Engr Dist, Albuquerque P.O. Box 1580 Albuquerque, New Mexico 87103
FALLEK, Henry G.	HANDAR, Inc. 3327 Kifer Road Santa Clara, California 95051
FARNSWORTH, Richard K.	National Weather Service, NOAA 8060 13th Street, Rm 721 Silver Spring, Maryland 20910
FARREL, Dan	SUTRON 1925 North Lynn Street Arlington, Virginia 22209
FELDMAN, Arlen	Hydrologic Engineering Center 609 Second Street Davis, California 95616
FIELD, Michael	U.S. Geological Survey National Center Reston, Virginia 22092

NAME	ADDRESS
FISHER, Paul	Department of the Army Office, Chief of Engineers DAEN-CWE-S Washington, DC 20314
FORNWALT, CPT Mark	U.S. Army Engineer Topographic Laboratories ATTN: ETL-GS-P Fort Belvoir, Virginia 22060
*FRANKENSTEIN, David	US Army Engr Dist, Wilmington ATTN: SAWEN-E P.O. Box 1890 Wilmington, North Carolina 28402
FREW, Ron	Dames and Moore Suite 700, 7101 Wisconsin Avenue Washington, DC 20014
GALLEY, CPT David R.	U.S. Army Engineer Topographic Laboratories ATTN: ETL-TAC Fort Belvoir, Virginia 22060
GALSTER, Richard	US Army Engr Dist, Seattle P.O. Box C-3755 Seattle, Washington 98124
GELNETT, Ronald	MARS, Inc. Suite 150G 4350 East Camelback Road Phoenix, Arizona 85018
GENSLER, Robert	Greenhorne & O'Mara, Inc. 6715 Kenilworth Avenue Riverdale, Maryland 20840
GILBERT, Michael	US Army Engr Div, Missouri River ATTN: Regulatory Functions Branch P.O. Box 5 Omaha, Nebraska 68101
GODWIN, B. C.	Department of the Army Office, Chief of Engineers DAEN-CWO-M Washington, DC 20314

NAME	ADDRESS
GORDON, Judith	US Army Engr Dist, New Orleans ATTN: Planning Division, Economic and Social Analysis Branch P.O. Box 60267 New Orleans, Louisiana 70160
GRAYBEAL, Ken	US Army Engr Dist, Seattle P.O. Box C-3755 Seattle, Washington 98124
GREEN, Dr. Gary	US Army Engr Dist, Saint Paul 1135 USPO & Custom House Saint Paul, Minnesota 55101
GREENE, Brian	US Army Engr Dist, Buffalo 1776 Niagara Street Buffalo, New York 14201
GRIER, David	Institute for Water Resources Kingman Building Fort Belvoir, Virginia 22060
GRIFFIN, Gene	U.S. Army Engineer Topographic Laboratories ATTN: ETL-TDL Fort Belvoir, Virginia 22060
GUSS, Philip	U.S. Geological Survey, NCIC 507 National Center Reston, Virginia 22092
HACUNDA, LT Michael	Defense Mapping School Fort Belvoir, Virginia 22060
HAMILTON, Roger	Department of the Army Office, Chief of Engineers DAEN-CWO-R Washington, DC 20314
*HARLOW, Charles	Louisiana State University Environmental Engineering and Management Mechanical Engineering Division of Engineering Research Baton Rouge, Louisiana 70803

NAME	ADDRESS
HART, Peter	US Army Engr Dist, Baltimore P.O. Box 1715 Baltimore, Maryland 21203
HENLEY, Ponder	U.S. Army Engineer Topographic Laboratories ATTN: ETL-TAC Fort Belvoir, Virginia 22060
HIGHT, Ralphord	US Army Engr Dist, Tulsa P.O. Box 61 Tulsa, Oklahoma 74121
*HILL, Jack	Louisiana State University Environmental Engineering and Management Mechanical Engineering Division of Engineering Research Baton Rouge, Louisiana 70803
HOLMES, Scott	US Army Engr Dist, Portland P.O. Box 2946 Portland, Oregon 97208
HOMYAK, Eugene	US Army Engr Dist, Pittsburgh 1000 Liberty Avenue Pittsburgh, Pennsylvania 15222
HORNE, Jack	US Army Engr Dist, Omaha P.O. Box 103, Downtown Station Omaha, Nebraska 68102
HOUSLEY, John	Department of the Army Office, Chief of Engineers DAEN-CWP Washington, DC 20314
HUDSON, Frank	US Army Engr Dist, Vicksburg P.O. Box 60 Vicksburg, Mississippi 39180
JARRY, Jean	French Embassy 2011 Eye Street, Northwest Washington, DC 20006

NAME	ADDRESS
JEWETT, Mel	US Army Engr Dist, Kansas City ATTN: MRKOD-P 601 East 12th Street Kansas City, Missouri 64106
JOHNSON, Everett	US Army Engr Dist, New Orleans ATTN: Planning Division Economic and Social Analysis Branch P.O. Box 60267 New Orleans, Louisiana 70160
JOHNSON, MG James	Department of the Army Office, Chief of Engineers DAEN-ZB Washington, DC 20314
JOHNSON, Norwyn	US Army Engr Div, Lower Mississippi Valley P.O. Box 80 Vicksburg, Mississippi 39180
JORGENSON, Paul	Department of the Army Office, Chief of Engineers DAEN-CWM-R Washington, DC 20314
KEEFER, Tom	SUTRON 1925 North Lynn Street Arlington, Virginia 22209
KERN, Jeffrey	HRB Singer, Inc. P.O. Box 60 Science Park Road State College, Pennsylvania 16801
KLEMAS, Dr. Victor	College of Marine Studies University of Delaware Newark, Delaware 19711
KREISLE, William	US Army Engr Dist, Louisville P.O. Box 59 Louisville, Kentucky 40201
KRUSINGER, Alan	U.S. Army Engineer Topographic Laboratories ATTN: ETL-RI Fort Belvoir, Virginia 22060

NAME	ADDRESS
KUDIS, Gary A.	950 L'Enfant Plaza Washington, DC 20024
KULES, Ken	US Army Engr Dist, Los Angeles 300 North Los Angeles Street P.O. Box 2711 Los Angeles, California 90053
KUTSCHEID, Ben	US Army Engr Dist, Wilmington P.O. Box 7002 Anchorage, Alaska 99501
LABYAK, Leo F.	U.S. Army Training and Doctrine Command ATTN: ATEN-FE-NR Fort Monroe, Virginia 23651
LAMBER, C. Kurt	US Army Engr Dist, New York ATTN: Foundations and Materials Br 26 Federal Plaza New York, New York 10007
LAMBSON, LT	Department of the Army Office, Chief of Engineers DAEN-CWP Washington, DC 20314
LAMM, Hans J.	US Army Engr Dist, San Francisco 211 Main Street San Francisco, California 94105
LATHROP, George N.	US Army Engr Div, Missouri River 12565 West Centre Road P.O. Box 103, Downtown Station Omaha, Nebraska 68102
LAUTERBORN, Tom	U.S. Geological Survey National Center Reston, Virginia 22092
LAYMAN, Robert	Dartmouth College Physics Department Hanover, New Hampshire 03755

NAME	ADDRESS
LEIGHTY, Dr. R. D.	U.S. Army Engineer Topographic Laboratories ATTN: ETL-RI Fort Belvoir, Virginia 22060
LICHY, David	U.S. Army Coastal Engineering Research Center Kingman Building Fort Belvoir, Virginia 22060
LINK, Dr. Lewis E.	U.S. Army Engineer Waterways Experiment Station P.O. Box 631 Vicksburg, Mississippi 39180
LINDER, Walter	US Army Engr Dist, Kansas City 700 Federal Building Kansas City, Missouri 64106
LONG, Coleman	US Army Engr Dist, Wilmington P.O. Box 1890 Wilmington, North Carolina 28402
LYCAN, Colonel Daniel	Commander and Director U.S. Army Engineer Topographic Laboratories Fort Belvoir, Virginia 22060
LYNCH, Matthew	Photographic Interpretation Corporation P.O. Box 868 Hanover, New Hampshire 03755
MACCHIA, Robert	U.S. Army Engineer Topographic Laboratories ATTN: ETL-TD Fort Belvoir, Virginia 22060
MADDOX, Silas	Department of the Army Office, Chief of Engineers DAEN-ZCM Washington, DC 20314
MALM, Rich	Department of the Army Office, Chief of Engineers DAEN-CWE-BA Washington, DC 20314

NAME	ADDRESS
MARAGOS, Dr. James	US Army Engr Div, Pacific Ocean Building 230 Fort Shafter, Hawaii 96858
MARLAR, Tom	U.S. Army Cold Regions Research and Engineering Laboratory P.O. Box 282 Hanover, New Hampshire 03755
MARTIN, Lynn	Department of the Army Office, Chief of Engineers DAEN-CWE-BU Washington, DC 20314
MARTIN, Melvin	Department of the Army Office, Chief of Engineers DAEN-RDC Washington, DC 20314
MARTUCCI, L. M.	Battelle Pacific Northwest Labs P.O. Box 999 Richland, Washington 99352
MATTHEWS, James S.	US Army Engr Div, Ohio River P.O. Box 1159 Cincinnati, Ohio 45201
MATTHEWSON, Robert	HRB Singer, Inc. P.O. Box 60 Science Park Road State College, Pennsylvania 16801
MAXFIELD, Donald	Department of Geography Northern Illinois University DeKalb, Illinois 60115
McGINNIS, David	Department of Commerce NOAA Washington, DC 20033
McINTOSH, Wayne	Department of the Army Office, Chief of Engineers DAEN-CWE-S Washington, DC 20314

NAME	ADDRESS
McKIM, Dr. H.	U.S. Army Cold Regions Research and Engineering Laboratory P.O. Box 282 Hanover, New Hampshire 03755
McQUIVEY, Raul	SUTRON 1925 North Lynn Street Arlington, Virginia 22209
MERRY, Carolyn	U.S. Army Cold Regions Research and Engineering Laboratory P.O. Box 282 Hanover, New Hampshire 03755
MESSMORE, Jeffrey	U.S. Army Engineer Topographic Laboratories ATTN: ETL-GS-P Fort Belvoir, Virginia 22060
MILLER, Holbrook	Department of the Army Office, Chief of Engineers DAEN-DS Washington, DC 20314
*MILLER, Ralph	US Army Engr Dist, Omaha 6014 USPO & Court House Omaha, Nebraska 68102
MINTER, David A.	Greenhorne & O'Mara, Inc. 10710 Lee Highway, Suite 202 Fairfax, Virginia 22030
*MONTANARI, John	National Wetland Inventory Suite 217, Dade Building 9620 Executive Center Drive Saint Petersburg, Florida 33702
MORRISSEY, Dr. A. C.	Office of Science & Technology 17th & Pennsylvania Ave, NW Old Executive Office Bldg, Rm 481 Washington, DC 20500
MOULTON, CPT David	Defense Mapping School Fort Belvoir, Virginia 22060

NAME	ADDRESS
MULLER, Richard	US Army Engr Dist, Norfolk 803 Front Street Norfolk, Virginia 23510
MURNAN, Kenneth	US Army Engr Dist, Omaha 6014 USPO & Court House Omaha, Nebraska 68102
MURPHY, L. P.	U.S. Army Engineer Topographic Laboratories ATTN: ETL-GS-P Fort Belvoir, Virginia 22060
NAGLE, John J.	Department of Commerce NOAA/NESS Washington, DC 20033
NELSON, Denis	Environmental Protection Agency 1860 Lincoln Street, Suite 900 Denver, Colorado 80295
NEWBURY, Claudia	U.S. Army Engineer Topographic Laboratories ATTN: ETL-TAC Fort Belvoir, Virginia 22060
NEWBURY, George E.M.	U.S. Army Engineer Topographic Laboratories ATTN: ETL-C Fort Belvoir, Virginia 22060
NEWKIRK, Tom	U.S. Army Training and Doctrine Command ATTN: ATEN-FE-NR Fort Monroe, Virginia 23651
NICHOLS, John	Water Resources Support Center Kingman Building Fort Belvoir, Virginia 22060
NIEMANN, Kenneth	US Army Engr Dist, Kansas City 700 Federal Building Kansas City, Missouri 64106
NOCELLA, Richard F.	US Army Engr Dist, Philadelphia Custom House & Chestnut Streets Philadelphia, Pennsylvania 19106

NAME	ADDRESS
NORDHILL, Daniel	US Army Engr Div, North Pacific P.O. Box 2870 Portland, Oregon 97208
NULL, Harold	US Army Engr Dist, Mobile P.O. Box 2288 Mobile, Alabama 36628
NYC, Rudy	National Wetland Inventory Suite 217, Dade Building 9620 Executive Building Saint Petersburg, Florida 33702
ORR, Donald	U.S. Geological Survey EROS Data Center Sioux Falls, South Dakota 57101
ORY, Tom	Director, Applications Division Daedalus Enterprises, Inc. P.O. Box 1869 Ann Arbor, Michigan 48106
OTTO, John A.	Eastman Kodak Company 343 State Street G&EMS 7-10 Rochester, New York 14650
PAREZ, John J.	US Army Engr Div, North Central 536 South Clark Street Chicago, Illinois 60605
PARRILLO, Daniel	US Army Engr Div, South Pacific 630 Sansome Street San Francisco, California 94111
PARSONS, Bonnie	Synergetics P.O. Box E Boulder, Colorado 80306
PAVLIDES, Michael	Greenhorne & O'Mara 6715 Kenilworth Avenue Riverdale, Maryland 20840
PENROD, James	Photographic Sciences, Inc. 7840 Airpark Road Gaithersburg, Maryland 20760

NAME	ADDRESS
PEARSON, Alex	16250 Neabsco Road Woodbridge, Virginia 22191
PERDUE, George	Engineering Plans and Services Div Directorate of Facilities Engineering Fort Benning, Georgia 31905
PETERSON, Robert K.	Goodyear Aerospace Corporation P.O. Box 85 Litchfield Park, Arizona 85340
PETIT, David	US Army Engr Dist, Galveston P.O. Box 1229 Galveston, Texas 77553
PHIPPEN, George	Department of the Army Office, Chief of Engineers DAEN-CWA-F Washington, DC 20314
PIERARD, Kevin M.	US Army Engr Dist, Chicago 219 South Dearborn Street Chicago, Illinois 60604
PIERCE, Phil	Department of the Army Office, Chief of Engineers DAEN-CWA-A Washington, DC 20314
PIRIE, Douglas	US Army Engr Dist, San Francisco 211 Main Street San Francisco, California 94105
PISTORINO, Charles	Department of the Army Office, Chief of Engineers DAEN-CCP Washington, DC 20314
PREBLE, Duane	SUTRON 1925 North Lynn Street Arlington, Virginia 22209
PRECHTEL, MAJ Earl	Defense Mapping School Fort Belvoir, Virginia 22060

NAME	ADDRESS
PRITCHETT, Edward C.	US Army Engr Div, North Pacific P.O. Box 2870 Portland, Oregon 97208
*POWER, Dr. John M.	Water Resources Branch, Environment Canada 10th Floor, Place Vincent Massey Ottawa, Ontario, Canada K1A 0E7
QUINN, A. O.	Quinn & Associates 460 Caredean Drive Horsham, Pennsylvania 19044
QUARLES, Dwight	Department of the Army Office, Chief of Engineers DAEN-CWO-R Washington, DC 20314
RAKETICH, Walter	US Army Engr Dist, Los Angeles 300 North Los Angeles Street Los Angeles, California 90053
RAKUS, Jill	US Army Engr Dist, Rock Island Clock Tower Building Rock Island, Illinois 61201
RANEY, Dr. William	Mail Code ETS-6 NASA Headquarters Washington, DC 20546
RAO, Chelluri N.	US Army Engr Dist, Chicago 219 South Dearborn Street Chicago, Illinois 60604
RAY, Griffith	US Army Engr Div, Ohio River P.O. Box 1159 Cincinnati, Ohio 45201
REDFIELD, Alice	Dames and Moore Suite 700, 7101 Wisconsin Avenue Washington, DC 20014
REIMER, Allen H.	U.S. Army Engineer Topographic Laboratories ATTN: ETL-TAC Fort Belvoir, Virginia 22060

NAME	ADDRESS
RIEBE, William	US Army Engr Dist, Rock Island Clock Tower Building Rock Island, Illinois 61201
ROBINSON, BG Hugh G.	Deputy Director of Civil Works DAEN-CWZ-B Office, Chief of Engineers Washington, DC 20314
ROGERS, Robert H.	Environmental Research Institute of Michigan P.O. Box 8618 Ann Arbor, Michigan 48107
ROSE, James	Underwater Resources, Inc. 8121 Georgia Avenue Silver Springs, Maryland 20910
ROXEY, Donna	US Army Engr Dist, Albuquerque P.O. Box 1580 Albuquerque, New Mexico 87103
ROY, James	Chief, Geology & Exploration Section Foundations, Materials and Survey Branch Building 230 Fort Shafter, Hawaii 96858
ROYAL, Al	General Electric Company 5030 Herzel Plaza Beltsville, Maryland 20705
RUCKER, Charles	US Army Engr Dist, Kansas City 601 East 12th Street Kansas City, Missouri 04106
RULON, LT(jg) Tim	NOS EDL C61 6001 Executive Boulevard Rockville, Maryland 20852
RUNDQUIST, Dr. Donald	Remote Sensing Applications Lab University of Nebraska at Omaha 3618 S. 91st Street Omaha, Nebraska 68124

NAME	ADDRESS
SALOMONSON, Vincent	Mail Code ETS-6 NASA Headquarters Washington, DC 20546
SAMUEL, Julie	Department of the Army Office, Chief of Engineers DAEN-CWE-BU Washington, DC 20314
SARANDIS, George T.	US Army Engr Dist, New England 424 Trapelo Road Waltham, Massachusetts 02154
SAUNDERS, Dr. Lloyd	US Army Engr Dist, Jacksonville P.O. Box 4970 Jacksonville, Florida 32201
SCHERZ, Dr. James	128 Lathrop Street Madison, Wisconsin 53705
*SCHLADENSKY, George	Directorate of Facilities Engineering ATTN: Engineering Plans and Services Branch Fort Benning, Georgia 31905
SERIO, Peirre	US Army Engr Dist, New Orleans P.O. Box 60267 New Orleans, Louisiana 70160
SEWELL, Eldon	Autometric, Inc. 5205 Leesburg Pike Falls Church, Virginia 22041
SHARP, Warren L.	US Army Engr Div, Lower Mississippi Valley P.O. Box 80 Vicksburg, Mississippi 39180
SHENK, Clair	US Army Engr Dist, Jacksonville P.O. Box 4970 Jacksonville, Florida 32201
SHOPE, William	U.S. Geological Survey National Center Reston, Virginia 22092

NAME	ADDRESS
SHUBINSKI, Robert	Water Resources Engineers 8001 Forbes Place Suite 312 Springfield, Virginia 22151
SIMONS, Jay	Greenhorne & O'Mara 6715 Kenilworth Avenue Riverdale, Maryland 20840
SLEZAK, William	US Army Engr Dist, New York 26 Federal Plaza New York, New York 10007
SMEDS, CPT R.	Defense Mapping School Fort Belvoir, Virginia 22060
SMITH, Milburn	US Army Engr Dist, Fort Worth P.O. Box 17300 Fort Worth, Texas 76102
SMITH, Terrence	US Army Engr Div, North Central 536 S. Clark Street, Rm 383 Chicago, Illinois 60605
SPOHN, Clifford	National Engineering Satellite Service Federal Building 4 National Oceanic and Atmospheric Administration Washington, DC 20233
SPRINGER, Denis	Autometric, Inc. 5205 Leesburg Pike Falls Church, Virginia 22041
SOYKE, Paul	US Army Engr Dist, Rock Island Clock Tower Building Rock Island, Illinois 61201
STALEY, George	US Army Engr Dist, Chicago 219 South Dearborn Street Chicago, Illinois 60604
STEVENS, Alan	U.S. Geological Survey National Center Reston, Virginia 22092

NAME	ADDRESS
STOLL, Jack	U.S. Army Engineer Waterways Experiment Station P.O. Box 608 Vicksburg, Mississippi 39180
STONE, Philip	US Army Engr Dist, Huntington Federal Building Huntington, West Virginia 25721
STRUVE, Horton	U.S. Army Engineer Waterways Experiment Station P.O. Box 608 Vicksburg, Mississippi 39180
SUSTAR, John	US Army Engr Dist, San Francisco 211 Main Street San Francisco, California 94105
SUTTERFIELD, Stephen	U.S. Army Engineer Topographic Laboratories ATTN: ETL-TAC Fort Belvoir, Virginia 22060
SVEUM, Duane	US Army Engr Div, Missouri River P.O. Box 103, Downtown Station Omaha, Nebraska 68101
TAI, John	Department of the Army Office, Chief of Engineers DAEN-DSE Washington, DC 20314
*TAILLADE, Michel	French Embassy 2011 Eye Street, Northwest Washington, DC 20006
TAYLOR, Richard	U.S. Army Engineer Topographic Laboratories ATTN: ETL-TAC Fort Belvoir, Virginia 22060
TAYLOR, Robert	Water Resources Engineers 8001 Forbes Place Springfield, Virginia 22003

NAME	ADDRESS
THEIS, Joe	Bausch & Lomb 5731 Crawford Crive Rockville, Maryland 20851
THOME, Pitt	NASA Headquarters Code ER-2 Washington, DC 20546
*TRAUTWEIN, Charles	U.S. Geological Survey EROS Program Sioux Falls, South Dakota 57101
TREIBER, Miklos	U.S. Army Engineer Topographic Laboratories ATTN: ETL-RI Fort Belvoir, Virginia 22060
TUIAHOV, Alex	NASA Headquarters Code ETS-6 Washington, DC 20546
TSENG, Ming-Te	Department of the Army Office, Chief of Engineers DAEN-CWE Washington, DC 20314
UNGAR, Stephen	NASA Goddard Institute for Space Studies 2880 Broadway New York, New York 10025
VANCE, Donald	Greenhorne & O'Mara 6715 Kenilworth Avenue Riverdale, Maryland 20840
VENTO, John	US Army Engr Div, North Central 536 South Clark Street Chicago, Illinois 60605
VENTOLA, Ronlad	US Army Engr Dist, New Orleans P.O. Box 60267 New Orleans, Louisiana 70160
VEN VERTLOH, Tom	Bausch & Lomb 5731 Crawford Drive Rockville, Maryland 20851

NAME	ADDRESS
*VON FINGER, Kevin	U.S. Army Air Defense Center and Fort Bliss ATTN: ATZC-FEE Fort Bliss, Texas 79916
WAGUESPACK, Leslie S.	US Army Engr Dist, New Orleans P.O. Box 60267 New Orleans, Louisiana 70160
WAHUS, David	US Army Engr Dist, Savannah P.O. Box 889 Savannah, Georgia 31402
WALL, James D.	US Army Engr Div, South Atlantic 510 Title Building 30 Pryor Street, Southwest Atlanta, Georgia 31905
*WALSH, Merv	Environmental Research Institute of Michigan P.O. Box 8618 3300 Plymouth Road Ann Arbor, Michigan 48107
*WANKET, A. E.	US Army Engr Div, South Pacific 630 Sansome Street, Rm 1216 San Francisco, California 94111
WEDLER, Edward	Ontario Center for Remote Sensing 880 Bay Street, 3rd Floor Toronto, Ontario, Canada M1S 5Z8
WEILL, Gilbert	French Embassy 2011 Eye Street, Northwest Washington, DC 20006
WELLENDORF, S.	MARS, Inc. 4350 East Camelback Road Phoenix, Arizona 85018
WHITE, James	Photo Sciences, Inc. 7840 Airpark Road Gaithersburg, Maryland 20760

NAME	ADDRESS
WHITEHURST, C. A.	Louisiana State University Environmental Engineering and Management Mechanical Engineering Division of Engineering Research Baton Rouge, Louisiana 70803
WHITEHOUSE, Alfred	US Army Engr Dist, Pittsburgh 1000 Liberty Avenue Pittsburgh, Pennsylvania 15222
WHITNEY, Linwood	National Environmental Satellite Service S311 World Weather Building, Rm 711F 5200 Auth Road Camp Springs, Maryland 20233
WHITT, Ken	SUTRON 1925 North Lynn Street Arlington, Virginia 22209
*WIENER, Saul	Coastal Zone Management P.O. Box 1889 Trenton, New Jersey 08625
WILCOX, Robert	US Army Engr Dist, Vicksburg P.O. Box 60 Vicksburg, Mississippi 39180
*WILLIS, William	US Army Engr Dist, Detroit P.O. Box 1027 Detroit, Michigan 48231
WOHLERT, Ronald	US Army Engr Dist, Buffalo 1776 Niagara Street Buffalo, New York 14207
WOOD, Robert	US Army Engr Dist, Los Angeles P.O. Box 2711 300 North Los Angeles Street Los Angeles, California 90053
WRIGHT, Janet	U.S. Army Engineer Topographic Laboratories ATTN: ETL-GS-P Fort Belvoir, Virginia 22060

NAME	ADDRESS
WUKELIC, George	Battelle Pacific Northwest Labs P.O. Box 999 Richland, Washington 99352
YANDRICH, Steven	US Army Engr Dist, New York 26 Federal Plaza New York, New York 10007
YARWASKY, Russ	Department of the Army Office, Chief of Engineers DAEN-CWB-C Washington, DC 20314
YORITOMO, Kent	U.S. Army Engineer Topographic Laboratories ATTN: ETL-GSL Fort Belvoir, Virginia 22060
YOST, Robert	US Army Engr Dist, Huntington P.O. Box 2127 Huntington, West Virginia 25721
YOUNG, LCDR Wayne	CG/COE Liaison, DAEN-CWO 20 Massachusetts Avenue Washington, DC 20314

*Unable to attend

☆ U. S. GOVERNMENT PRINTING OFFICE : 1980 622-891/1285